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Snout Ventilation and Cooling Effects on Swine

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SNOUT VENTILATION AND COOLING EFFECTS ON SWINE

by

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This thesis is approved as a creditable and independent investigation by a candidate for the degree, Master of Science, and is acceptable as meeting the thesis requirements for this degree. Acceptance of this thesis does not imply that the conclusions reached by the candidate are necessarily the conclusions of the major department.

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INTRODUCTION

Providing a suitable environment for lactating sows and young piglets during summer climatic conditions is one of the most critical engineering design challenges in the livestock industry. Young piglets perform best at environmental temperatures 5 to 10 degrees celsius (9-18 degrees F) higher than the optimal temperature for sows. Summer climatic conditions often result in a thermal environment quite suitable for young piglets, but not suitable for the sows. There is a need to modify the thermal environment for the sow to obtain the desired thermal environments.

Technological advances have improved conditions for rearing pigs in cold weather. Ross (1960) reported that -29 degrees celsius (-20 degrees F) weather is preferable to 35 degrees celsius (95 degrees F) for farrowing because facilities and equipment are developed which effectively maintain the desired thermal environments for sows and piglets during cold weather conditions. Conventional ventilation systems in farrowing rooms may cause drafts on the piglets in attempting to cool the sow during warm weather. One of the requirements of baby pigs is the complete absence of drafts (Sainsbury, 1970). This indicates a need to investigate the performance and cost of zone cooling systems for warm weather conditions.

The commercial value of the 3.14 million hogs and pigs marketed by South Dakota farmers in 1980 was 278 million dollars. This represents 10 to 12 percent of the total agricultural product sales from South Dakota farms (Janssen, 1982), and ranks South Dakota among the top 10 hog production states. Researchers have documented increases in swine productivity through optimization of the thermal environment for farrowing facilities, which could result in increased profits for South Dakota farmers. Agricultural engineers must continue to develop and evaluate techniques for improving the animal environment to provide producers the means for enhancing productivity.

Benefits of relieving the sow of heat stress causes a need to modify the thermal environment in farrowing barns. Jensen (1964) stated that the cooling of the entire environment is impractical. Therefore, alternative methods of partial modification of the environment using a system that supplied mechanically refrigerated air and a second system that supplied regular outside air to the sow's head area were investigated. The objectives of this investigation were the following:

1. Compare swine performance as affected by three environmental alternatives for lactating sows: 1) cooled air directed at the sow head area plus conventional ventilation, 2) outside air directed toward the sow head area plus conventional ventilation, and 3) conventional summer ventilation only.

2. Document the effects of the above listed environmental alternatives on swine performance as indicated by sow weight loss during lactation, sow feed consumption during lactation, piglet mortality, piglet weight gain to seven days of age, piglet weight gain during lactation, the time required for the sow to return to estrus after weaning, and sow respiration rates.

3. Evaluate the mechanical operation of the snout systems in the test facility in terms of energy requirements, system life, and maintenance requirements.

REVIEW OF LITERATURE

Air temperature, relative humidity, and velocity, often collectively termed the thermal environment, are critical factors affecting swine performance. Researchers agree that the optimal thermal environment is a function of ration, herd health, facility design, swine age, swine weight, environmental temperatures, air movement, and relative humidity. The complexity of swine physiology makes it impractical to try to define the optimal thermal environment for all possible conditions. However, this problem can be simplified by limiting variables to those of typical farrowing facilities and management practices.

Animal Comfort:

"Thermoneutral Zone" is a concept, not uniformily defined, which corresponds to a comfortable animal environment where the best feed efficency, growth, and milk production are achieved. Considerable research effort has been directed toward development of simple ways of determining this zone, but the complexities of physiology and the number of variables affecting this zone make precise definitions impractical. Bruce (1981) defined the thermoneutral zone for the pig as "that within which the pig's heat production is independent of temperature, and which may be identified with the zone of maximum productivity". Heat production by the pig within this zone is primarily determined by the pig's weight, assuming conventional management practices at typical swine facilities. There is a decrease in rate of weight gain outside the optimal temperature range (Hazen and Mangold, 1960).

Ingram (1974) defined the thermoneutral zone for swine to be the range of ambient conditions, usually defined by environmental dry-bulb temperatures, within which the animal can thermoregulate by variations in tissue insulation. Lower critical temperature is the lowest ambient temperature at which resting metabolic rate remains minimal. Upper critical temperature is sometimes defined as the highest ambient temperature at which metabolic rate remains minimal, but Ingram (1974) suggested that perhaps the upper critical temperature is best considered as the ambient temperature above which the pig increases evaporative heat loss to dissipate excess heat. The values for the upper critical temperature estimated by these two methods are not the same.

Bruce (1981) stated that the lower critical temperature varies with feeding level, weight, and flooring type. Air velocity also affects the lower critical temperature (Close et al., 1981). The upper critical temperature is affected by feeding level, weight, type of flooring, and moisture conditions (Bruce, 1981). Moisture conditions refer to the opportunity for wallowing, which is the pig's method of wetting the skin surface to increase the evaporative cooling rate since the pig does not sweat (Mount, 1966a). A number of other factors such as air velocity, radient temperature, and previous climatic history affect these temperature values (Ingram, 1974).

An important physiological characteristic of the pig is its inability to sweat. Eccrine glands, abundant on human skin surfaces, permit sweating, and the pig has these glands on the snout and lips. The rest of the pig's skin contains aprocine glands, which do not permit sweating (Montogna, 1966). This results in the pig having a narrow zone of thermal neutrality (Mount, 1966). Mount (1968) stated that the pig does not sweat in response to thermal stimuli and concluded that the pig loses less water from the skin than any other mammal which had been studied up to that time. Although the pig is considered to be nonsweating, it can increase skin moisture loss by 2 to 3 times when hot (Morrison et al., 1967).

Heitman et al. (1958) concluded that 23 degrees celsius (74 degrees F) resulted in a maximum rate of gain for 45 kg (100 lb) hogs while 16 degrees celsius (61 degrees F) resulted in maximum weight gain for 160 kg (350 lb) hogs. Bond et al. (1959) found similar, but slightly different, optimal temperatures with 23 degrees celsius (74 degrees F) resulting in maximum weight gain for 45 kg (100 lb) hogs and 18 degrees celsius (64 degrees F) for 160 kg (350 lb) hogs. Bruce (1981) defined an upper critical temperature value range for a 140 kg (310 lb) sow of 22 to 28 degrees celsius (72-82 degrees F), depending on the type of floor.

Nursing piglets have a higher thermoneutral zone. Bruce (1981) estimated the lower critical temperature for a nursing pig to range from 25 to 31 degrees celsius (77-88 degrees F). Sainsbury (1970) determined the lower critical temperatures to be 35 degrees celsius (95 degrees F) at birth, 29 degrees celsius (84 degrees F) up to 4 kg (9 lb), and 24 degrees celsius (75 degrees F) up to 10 kg (22 lb) for piglets exposed to still air conditions (velocities less than .15 m/s (30 fpm)). Increasing the air velocity from below .15 m/s (30 fpm) to between .15 and .75 m/s (30-50 fpm) results in a 5.6 degrees celsius (10 degrees F) increase in these critical temperature values. McGinnis et al. (1981) estimated a lower critical temperature value of 34 degrees celsius (93 degrees F) for a newborn pig.

There is little, if any, overlap of the thermoneutral zones for the sow and litter. This leads to the conclusion that there is a need for 2 different environments in the farrowing room (Bruce, 1981; Karhnak and Aldrich, 1971; Butchbaker and Shanklin, 1965; Bond et al., 1952). Sow heat stress results from maintaining a farrowing room environment optimal for new born to weaning age pigs. Adverse effects of sow heat stress are decreased milk production, which decreases piglet growth, increased sow weight loss, and decreased resistance to disease organisms (Esmay, 1969). Heat stress is reflected in growth, production, and health (Esmay, 1969).

High ambient air temperatures sometimes decrease breeding efficency in swine. Teaque et al. (1968) found high ambient air temperature conditions decrease the ovulation rate, increase anestrus and the number of sows returning to estrus a second time, and decrease the percentage of gilts to become pregnant. Holmes (1973) found high ambient temperatures cause an increase in the maintenance requirements of swine.

Temperature regulating systems in baby pigs are not fully developed (Newland et al., 1952). The homeothermic abilities of young pigs are, therefore, easily exceeded (Butchbaker and Shanklin, 1965). The young piglet is suceptible to heat stress (Mount, 1968), but also has low heat production and high thermal conduction (Sainsbury, 1970). Curtis (1970) found that a newborn pig has little insulation and poor metabolic response, but after two days this metabolic response improves. At a temperature of 20 degrees celsius (68 degrees F), the metabolic rate of a newborn pig must double, relative to the thermonuetral metabolic rate, to maintain proper body temperature (Mount, 1968). Blecha and Kelley (1981) concluded that a single 2.5 hour exposure of piglets to cold air temperatures at birth reduces the subsequent acquisition of colostral immunoglobulin, which may contribute to preweaning mortality in piglets.

Modes of Heat Transfer:

The physiological response of swine to various environmental factors are related to the methods by which swine lose heat and moisture to the environment. Hazen and Mangold (1960) divided heat loss from swine into two modes, sensible and latent. Sensible heat loss includes conduction, convection, and radiation. The loss of heat energy through the adiabatic saturation of the air-vapor mixture from the lung cavity and sweating is the latent heat loss.

Conductive heat loss consists of heat loss from the pig to a surface in direct contact with the animal's skin surface, almost always the floor. Spillman and Hinkle (1971) investigated the effect of floor temperature on the conductive heat loss from swine to the floor and concluded that the temperature of the floor had no significant effect on the conductive heat loss to the floor, while ambient air temperature did have a significant effect on the conductive heat loss. Floor temperature and ambient air temperature interacted to have a significant effect on the conductive heat loss to the floor. Their investigation also showed that conductive heat loss to the floor from the hog was higher when the floor was maintained at 21 to 27 degrees celsius (70-80 degrees F) compared to when the floor was maintained at 18 degrees celsius (65 degrees F). Earlier work by Kelly et al. (1964) resulted in similar findings with conductive heat loss to the floor increasing when the floor temperature was raised to 21-27 degrees celsius (70-80 degrees F), then decreasing as the floor temperature was increased beyond the 21 to 27 degrees celsius (70-80 degree F) range.

Heat transfer to the exterior surfaces of the animal is mainly due to blood circulation. Skin blood flow was evidently reduced by the cooler slabs (Esmay, 1969), and reduced skin blood flow decreased the conductive heat loss. This physiological ability of the animal to effectively alter the conductivity between its body and the contacting surface means that conductive heat loss is not directly proportional to the temperature difference between body core temperature and the floor temperature. Investigations conducted by Spillman and Hinkle (1971) showed a maximum conduction heat loss rate at an ambient air temperature of 33 degrees celsius (90 degrees F) and a floor temperature of 24 degrees celsius (75 degrees F).

Convective heat loss is the heat transfer from the animal's skin surface to the air surrounding the animal. Close (1981) stated that increasing air movement increases convective heat loss from swine. The amount of energy lost through convection decreases as the ambient air temperature rises. If the ambient air temperature is equal to or above the body temperature of the pig, all potential for convective heat loss is gone (Esmay, 1969; Bond et al., 1965). Close (1981) stated that the extent to which air movement causes an increase in heat loss is dependent upon an animal's body weight, the temperature of exposure, and whether it is penned individually or in a group.

Younger animals are more susceptible to changes in air movement than older animals (Holmes and Mount, 1967). Similarly, low air velocity changes are proportionately more effective in increasing heat loss than similar changes at high wind speed (Mount, 1966b). The effect of air movement is also temperature-dependent, with the higher losses occurring at lower environmental temperatures (Close, 1981). For individual 25 kg (55 lb) pigs, each .05 m/s (10 fpm) increase in air movement above the wind speed at which forced convection predominates, .2 m/s (40 fpm), was equivalent to a 1 degree celsius (1.8 degrees F) decrease in air temperature. For 60 kg (130 lb) pigs, the effect was less, each .1 m/s (20 fpm) increase being equivalent to a 1 degree celsius (1.8 degrees F) decrease (Close, 1981). This effect will, however, diminish as air velocity decreases (Close, 1981). Groups of pigs are affected less by air velocity than individual pigs because of huddling and windbreak effects (Close, 1981). Sainsbury (1970) stated that one requirement of young piglets was the complete absence of drafts. Newborn piglets have low heat production and high energy losses, and therefore, can not tolerate even low air velocities, even when exposed to a warm environment.

Thermal radiation is the transfer of heat from one surface to another by electromagnetic waves. An energy exchange occurs when two bodies are within visual range of each other and are separated by a nonradiation absorbing medium. These are continuous processes of emission and absorption by each body. When the bodies are the same temperature the net heat exchange is zero. If they are at different temperatures, there is a net transfer of heat energy from the warmer to the colder body (Esmay, 1969). In fairly typical summer conditions for swine, radiation heat loss accounts for nearly 1/2 of the nonevaporative heat losses. Esmay (1969) also stated that radiative heat losses for swine may be considered to be about the same as convective losses since conductive heat losses to the floor are normally quite minimal. Increased air velocities substantially reduce radiative heat losses from swine due to the resulting lowering of the skin surface temperature (Bond et al., 1965).

Latent heat loss, the evaporation of moisture, is the fourth means of heat dissipation for swine. There are two ways for a pig to dissipate heat by evaporation of moisture, evaporation of moisture from the lung cavity and evaporation of moisture from the skin surface. Hazen and Mangold (1960) stated that the pig is considered to be nonsweating. Morrison et al. (1967) concluded that although the pig is considered to be nonsweating, the pig can increase skin moisture loss by 2 to 3 times when hot. Skin moisture loss amounted to approximately 50%, ranging from 35% to 67%, of the total moisture loss from the pig. These investigators also stated that an increase in air velocity caused a decrease in skin moisture loss. Iyengar (1974) investigated the use of an inspired-air cooling system for dairy cattle and stated that respiratory convective heat loss and respiratory latent heat loss remove heat from the respiratory cavity and are functions of the pulmonary ventilation rate and the inspired air properties.

The loss of heat by evaporation depends on the change of state of water from liquid to vapor, a process which takes up heat from the surroundings. In this case, the lungs. The actual quantity of heat energy involved depends on the latent heat of vaporization, the amount of water available within the lung cavity, the water vapor preasure within the lung cavity, the water vapor preasure of the environmental air, and the pulminary ventilation rate (Mount, 1968). McLean (1974) stated that the pig can dissipate only a small part of its heat production by evaporation from the respiratory tract, plus a small additional amount of heat by warming the inspired air when the ambient air temperature is below body temperature.

Morrison et al. (1967) found that when exposed to an environment of 29 degrees celsius (85 degrees F), the pig tripled lung moisture loss and doubled skin moisture loss compared to when exposed to 16 degrees celsius (60 degrees F). It was also found that as relative humidity increased, lung moisture loss decreased. This study concluded that the evaporization of moisture is the major avenue of heat loss at high ambient temperatures for swine.

Bond et al. (1952) studied the heat loss of swine at varying environmental temperatures for all modes of heat loss (figure 1). As environmental temperature rises, sensible heat loss from swine decreases and latent heat losses increase (Bruce, 1981; Spillman and Hinkle, 1971;

Esmay, 1969; Morrison et al., 1967). Bond et al. (1965) stated that at an environmental temperature equal to or above 40 degrees celsius (104 degrees F), all potential for convective heat loss is gone. If the environmental temperature is equal to or above the body temperature of the pig, all heat loss will be evaporative (Esmay, 1969; Hazen and Mangold, 1960; Mitchell and Kelley, 1938).

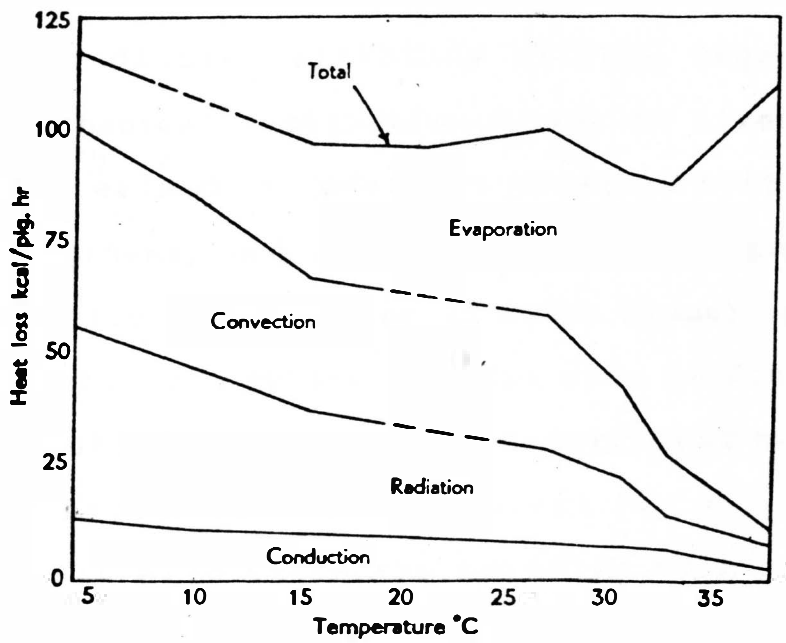

Figure 1. Partitional heat-loss diagram for a 26 to 37 kg pig (Bond et al., 1952).

(Values are for a pig in a group.)

Environmental Control Practices:

Ventilation is a system of air exchange which is intended to accomplish one or more of the following: 1) provide the desired amount of air, without drafts, to all parts of the shelter, 2) maintain temperatures within the shelter within desired limits, and 3) maintain the relative humidity within the shelter within desired limits (ASAE, 1985). The ventilation system also brings in oxygen needed to sustain life, carries out harmful gases and undesirable odors, and dilutes air-borne disease organisms (MWPS, 1983b). Mechanical ventilation sytems in livestock housing are characterized as: positive pressure systems, neutral pressure systems, and negative pressure systems, with the last being the most popular in swine houses (MWPS, 1983a). Positive pressure sytems utilize fans to force fresh air into the building, where it is distributed by a baffle or by a duct having outlets to control the air distribution pattern. Air also exits the building through cracks and planned outlets due to the pressure differential between indoors and outdoors. Neutral pressure systems utilize a fan (or fans) to introduce fresh air into the building, and a second fan (or fans) to remove air from the building, resulting in negligible static pressure difference between the building and its surroundings. Negative pressure systems utilize fans to force air out of the building with fresh air entering through cracks and planned inlets. Inlets are located in a manner to distribute the fresh air uniformily throughout the room (MWPS, 1983a).

As air velocity increases, convective and evaporative heat losses increase (Bond et al., 1965). Therefore, normal ventilation systems increase heat loss of animals during hot weather by increasing the airflow rate, thereby increasing the drafts on the animals. Air exchanges of 2.25 cubic meters per minute (80 cfm) for mild ambient temperatures and 14 cubic meters per minute (500 cfm) for hot ambient temperatures are recommended for each sow and litter, regardless of the type of mechanical ventilation system (MWPS, 1983a).

One supplemental cooling method used to cool swine at high ambient temperatures is evaporative cooling. Driggers (1980) tested the effects of spraying water in the form of a mist, referred to as a fogger system, on swine performance. This system delivered 7.6 litters (2 gal.) of water per hour at a preasure of 276 kilonewtons per square meter (40 psi) for 18 sows and 9 boars and resulted in improved sow and boar fertility. Systems of this type generally operate continuously, lowering the ambient air temperature through the sensible energy requirements to vaporize the water.

A more effective method is to wet the skin surface quickly and then allow the applied moisture to evaporate. This can be accomplished using timer-controlled sprinklers to deliver droplets to the skin surface (Nichols et al., 1982). Hazen and Mangold (1960) suggested that sprinklers should not be used at ambient temperatures below 27 degrees celsius (80 degrees F) to avoid chilling of the pigs. The main advantage of sytems of this type compared to air conditioning systems is reduced electrical usage. Driggers (1980) showed electrical usage for a zone cooling system to be 150 kW-h per sow maintained and 10 kW-h per pig marketed compared to 14 kW-h per sow maintained and .9 kW-h per pig marketed for a fan and fogger system.

Another supplemental method of cooling swine during hot weather is referred to as zone or snout cooling. This involves delivering cooled air to the head area of the pig, thus modifying the thermal environment of the pig. Hazen and Mangold (1960) stated that zone cooling of lactating sows appeared to be economically justifiable. Zone cooling has been shown to effectively reduce heat stress (Lipper, 1961). Hahn et al. (1965) conducted research to investigate the effect of inspired-air cooling on lactating dairy cows. Their results showed that inspired-air cooling increased feed intake and milk production, and decreased rectal temperatures and respiration rates.

Driggers (1976) tested zone cooling of boars and sows in a breeding facility and concluded that zone cooling resulted in a compatible thermal environment for the breeding animals. Research conducted by Lynch (1979) on the effects of zone cooling in the farrowing house on sow and litter performance showed no significant effects. This could be due to the mild ambient temperatures of 24 to 25 degrees celsius (75-77 degrees F) and 27 to 28 degrees celsius (81-82 degrees F) at which these tests were conducted. Zone cooling of lactating sows has been shown to have positive effects on swine performance. Merkel (1965) found zone cooling of lactating sows to reduce the respiration rates of the sows, increase sow feed consumption, increase litter weight gain, and decrease sow weight loss during lactation. Research conducted to investigate the effects of zone cooling on swine performance in a free stall type farrowing system revealed decreased sow respiration rates, which indicated a reduction in the effective temperature for the sows (Gannon, 1971).

EXPERIMENTAL PROCEDURE

Swine Facilities:

Research was conducted in a 30 crate, partially slatted, confinement type farrowing complex operated by Harvest States, GTA Feeds Division at Ellis, South Dakota (4 miles west of Sioux Falls) to evaluate the effects of snout cooling and snout ventilation on swine performance. The Harvest States Swine complex is operated similarly to typical commercial farrowing facilities. There are five identical farrowing rooms, each housing six sows and litters.

Sows were moved from a gestation barn into the farrowing rooms in groups of six approximately one or two days in advance of farrowing. After approximately three weeks of lactation, piglets were weaned and the sows were returned to the breeding and gestation barn. Schedules varied slightly to accommodate the sows which were ready to farrow. All sows were of similar genetic background, landrace cross large white, and all sows were provided "ad libitum" feed using the same lactation diet within each year. The diet was changed slightly for all sows for the summer of 1984, but in all cases the diet met the National Research Council (1979) ration recommendations.

Summer ventilation air is pulled through an eave inlet on the north side and exhausted on the south side through wall fans in accordance with Midwest Plan Service (1983a) recommendations. The sows face away from the center aisle in this facility. Water pipes, which are located in the concrete floor of the front part of the farrowing crates, provide a warm resting area for the young piglets. Heat lamps were also used during the first several days after farrowing.

A snout cooling system, which provided cooled air to twelve farrowing crates, was installed in two, six crate farrowing rooms and tested during the summers of 1982, 1983, and 1984. A snout ventilation system, which provided outside air to six farrowing crates, was installed in one, six crate farrowing room and tested during the summers of 1983 and 1984. Sows in three, six crate farrowing rooms acted as controls for the summer of 1982 and sows in two, six crate farrowing rooms acted as controls for the summers of 1983 and 1984. All farrowing rooms were identical except for the addition of the snout systems. The order of the farrowing rooms from west to east was: one snout ventilated room, two control rooms, and two snout cooled rooms.

Variables Measured:

Swine performance variables measured were: (1) sow weight loss during lactation, (2) sow feed consumption during lactation, (3) the number of days required for the sow to return to estrus after weaning, (4) piglet death loss during lactation, (5) weight gain of the piglets to seven days of age, (6) weight gain of the piglets during the entire lactation, and (7) sow respiration rates. Factorial analysis of variance with unequal subclass numbers was used to test the effects of the snout systems on these swine performance variables.

Sow weight loss during lactation was measured by weighing the sow the day after farrowing and again at weaning. This performance variable was stated in terms of weight loss per day per sow, since not all of the sows were lactating the same number of days.

The average lactational periods were not affected by the snout systems. The average lactations were 24.8 days for the snout cooled group, 23.6 days for the snout ventilated group, and 24.7 days for the control group. Average lactational periods for all sows were 24.4 days for the summer of 1982, 25.8 days for the summer of 1983, and 23.5 days for the summer of 1984.

Sow feed consumption was monitored by measuring the amount of feed distributed to each sow at each feeding, morning and afternoon. These amounts were then totalled and expressed in terms of weight of feed per day per sow so that differences in lactation periods would not invalidate feed consumption comparisons. Feed wastage was assumed similar for all groups. However, wastage was not measured.

Piglet weight gain was monitored by weighing the entire litter the day after farrowing, at seven days of age, and again at weaning. This variable was stated in terms of weight gain per day per piglet to compensate for varying lactational periods and litter sizes.

Piglet death loss was difficult to determine due to the practice of piglet transfering. Transfers were generally made within the first two days after farrowing to even out the number of piglets per sow. Data from 24 sows and their litters were deleted from the experimental analysis because transfers could not be properly accounted for in the analysis and interpretation. Piglet death loss could not be determined by subtracting the number of piglets weaned from the number of piglets farrowed. Therefore, piglet death loss was tabulated by separately recording deaths, and this was only done during the last two summers, 1983 and 1984.

The number of days required for the sow to return to estrus was monitored by recording the weaning date and the date of first estrus. The respiration rates of the sows were monitored manually with a stop watch during the summers of 1983 and 1984. Sow respiration rates were measured during the period of approximately 9:00 am until 4:00 pm, at one hour intervals, one day each week. Two sows from each farrowing room were chosen at random, one on the south and one on the north sides of the room. Wet and dry bulb temperatures within the sow's farrowing room were also measured at the same time using a sling psychrometer.

Each litter was assigned a number, for data identification purposes, during all three years. The number of the litter (i.e. first, second etc.) that the sow was presently nursing was also recorded during the third summer, 1984. The sows from the summer of 1984 were then seperated into three parity groups. Parity group 1 consisted of those sows which were nursing their first litter, parity group 2 was those sows which were nursing their second through seventh litter, and parity group 3 consisted of the remaining sows from the summer of 1984.

Environmental dry bulb temperatures, including those within the snout systems, were recorded using thermocouples connected to an automatic data acquisition system. A strip chart recorder was used when the data acquisition system was not available during the periods of: May 30, 1982 to October 16, 1982, June 10, 1983 to July 28, 1983, and September 11, 1984 to September 21, 1984. Each farrowing room had two, or more, thermocouples located at various points within the room to serve as a check on the temperature data (figures 2, 3 and 4). Incoming ventilation air and the outside air temperatures were also recorded. Thermocouples were located at various points within the snout systems.

Energy consumption of the air conditioning system was measured with the data acquisition system, when it was available, and a recording ammeter, otherwise. The data acquisition system recorded the average current drawn by the air conditioner and the hours of operation. Operation time was monitored by the recording ammeter during the periods of: May 30, 1982 to October 16, 1982, June 10, 1983 to July 28, 1983, and September 11, 1984 to September 21, 1984.

Ventilation airflow patterns were analyzed during the summer of 1984 to check for possible differences among rooms. Patterns were detected using smoke candles and recorded on video cassette for later study. Airflow patterns were checked in a similar manner, during the winter months, to determine whether the snout systems adversely affected the ventilation airflow patterns during winter conditions.

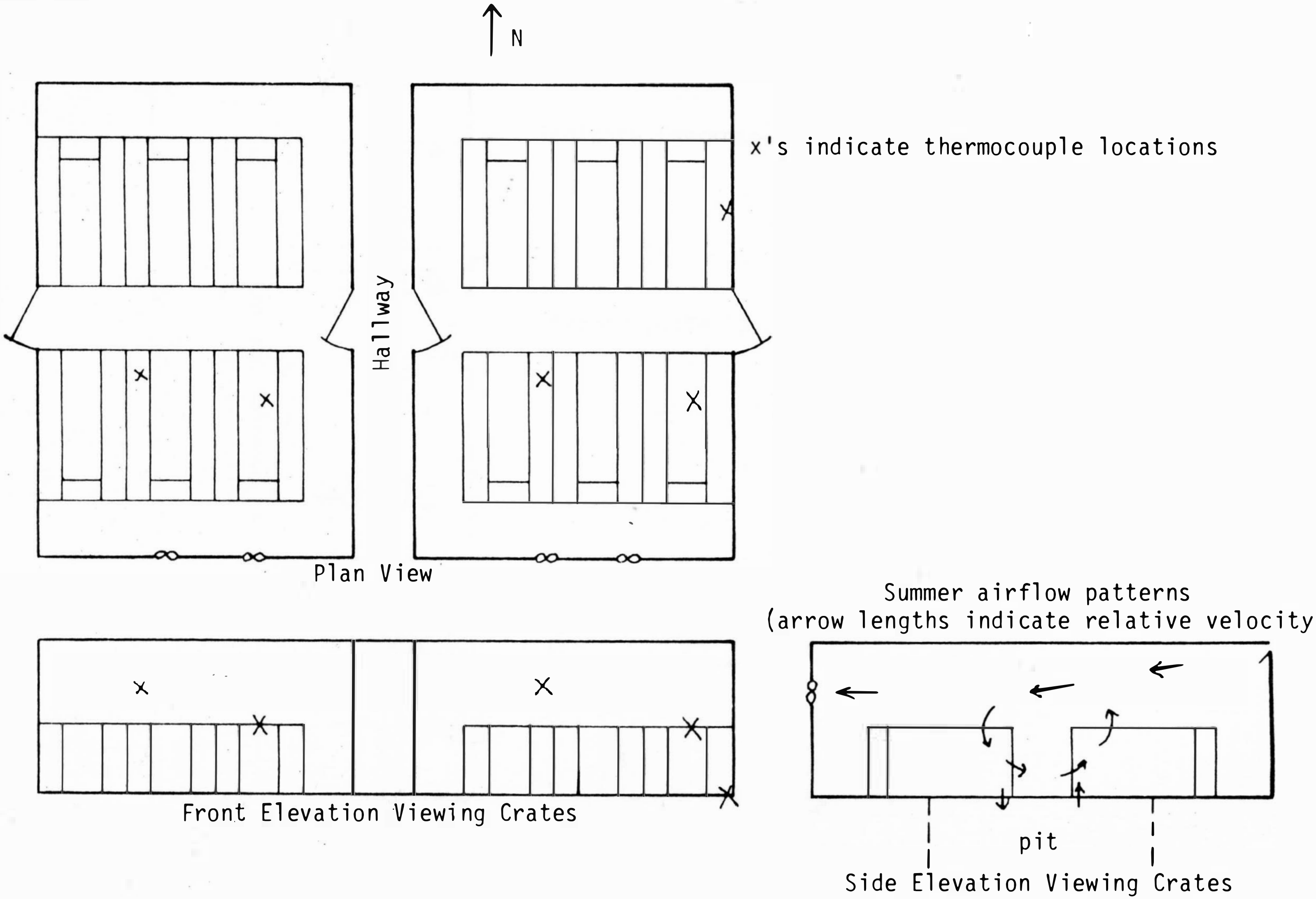

Figure 2. Control room schematic showing floor plans, thermocouple locations and airflow patterns

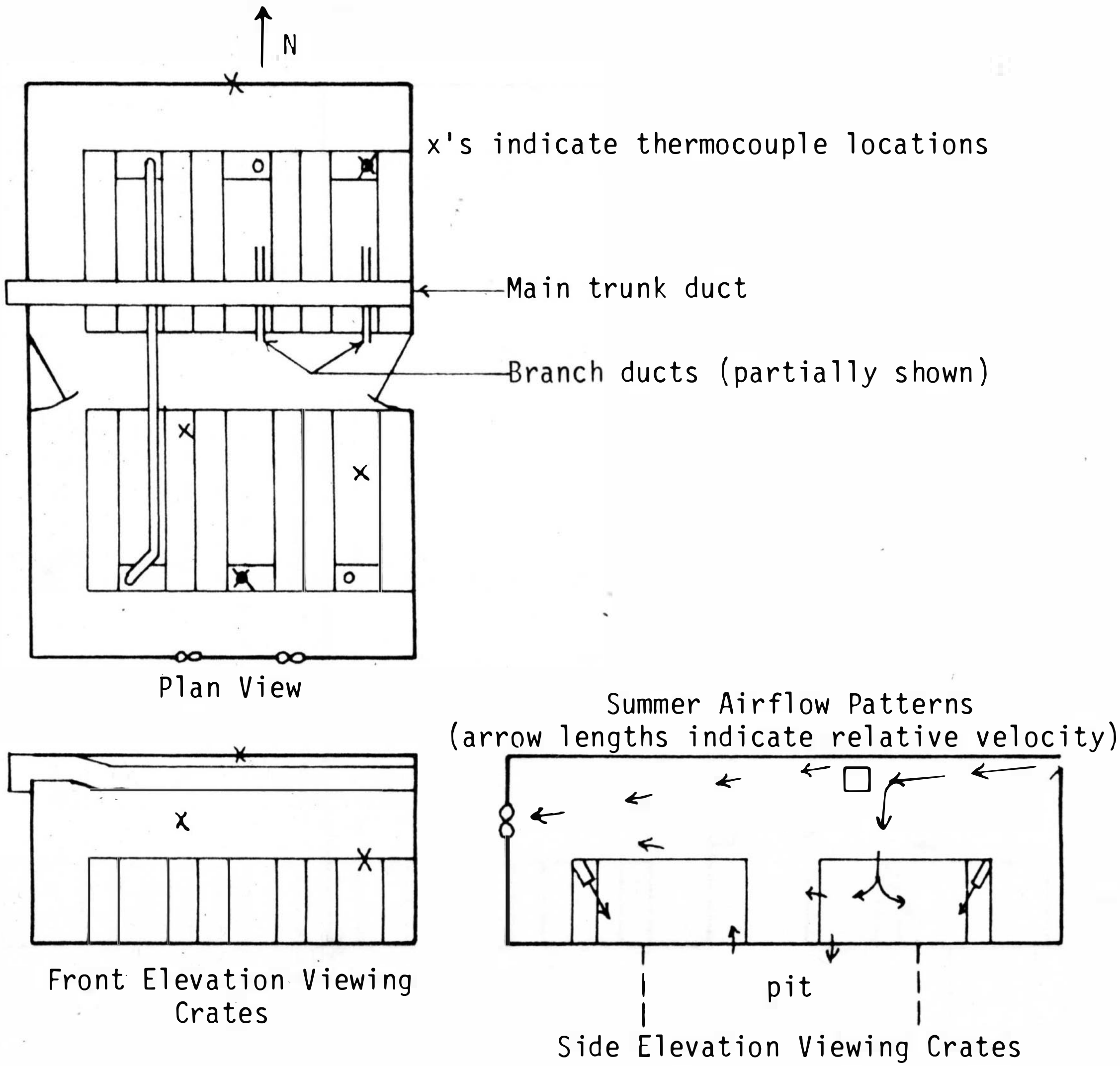

Figure 3. Snout ventilation room schematic showing floor plans, thermocouple locations and airflow patterns

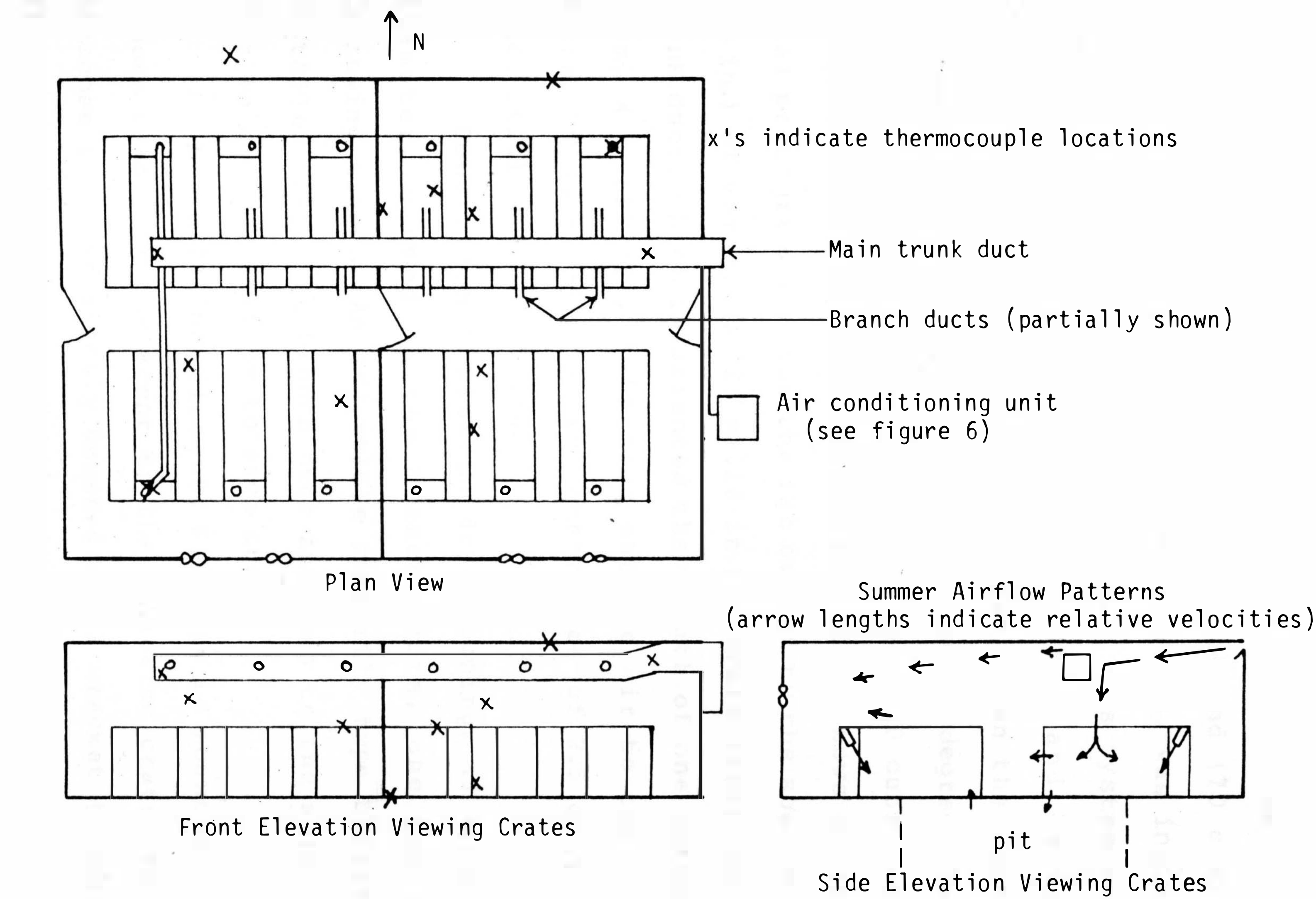

Figure 4. Snout cooling room schematic showing floor plans, thermocouple locations and airflow patterns

Description of Snout Ventilation System:

A snout ventilation system, which delivered approximately .034 cubic meters per second (70 cfm) per crate of outside air to six farrowing crates, was installed during the spring of 1983 (figure 3). This system was in operation during the summers of 1983 and 1984. A thermostatic control started the fan, when the room air temperature exceeded 24 degrees celsius (75 degrees F).

A forward curved blower provided .20 cubic meters per second (420 cfm) of outside air to the sows against a total preasure drop from the fan outlet to the sows of 2 cm (.8 in.) of water. A .25 m (10 in.), square cross-section trunk duct, which is oriented the length of one farrowing room, 4 m (13 ft), delivered outside air to the branch ducts. This trunk duct is constructed of 2.5 cm (1 in.) thick insulated duct board.

Conventional plastic dryer tubing, .1 m (4 in.) diameter, served as the branch ducts, one for each farrowing crate. An adjustible butterfly type baffle was installed where the branch duct attaches to the main trunk duct to balance airflow to each crate.

A .1 m (4 in.) diameter PVC pipe is mounted, using a hose clamp, to the front of the farrowing crate where it attaches to a permanently mounted metal bracket (figure 5). The metal bracket holds the PVC pipe at an angle of

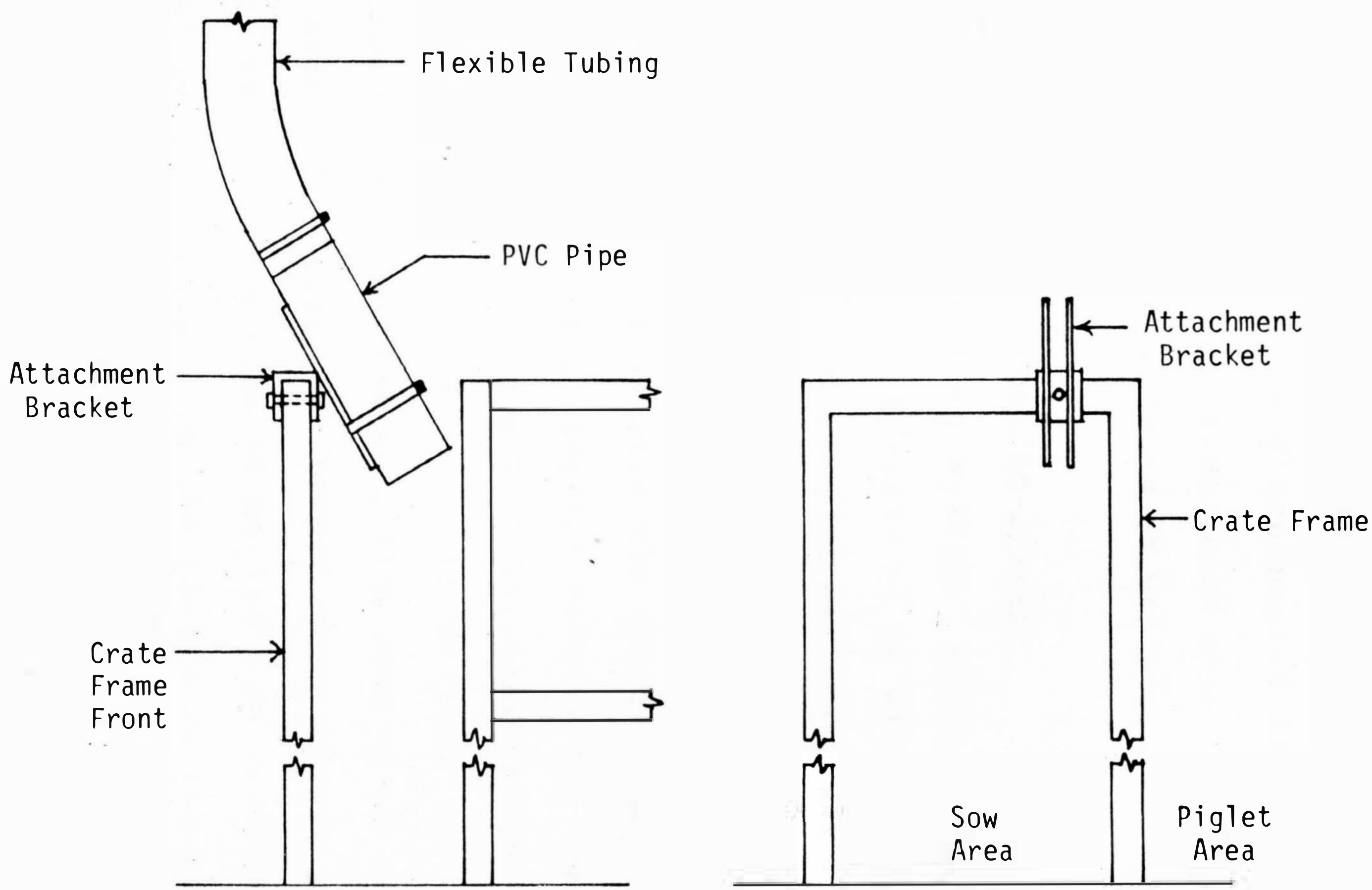

Figure 5. Branch duct attachment schematic

approximately 30 degrees from vertical. The flexible branch duct is fastened to the PVC pipe using a second hose clamp. The hose clamp is necessary so that the PVC pipe and branch duct can be disconnected from the farrowing crate, which allows the crate head gate to open and the sow to be moved out and replaced at weaning.

Description of Snout Cooling System:

A snout cooling system, which supplied a mean cooling effect of 585 W/crate at an airflow rate of .017 cubic meters per second (35 cfm) per crate was installed in two farrowing rooms, 12 crates (figure 4). This system was operated during the summers of 1982, 1983, and 1984. A thermostatic control started the system whenever room air temperature exceeded 24 degrees celsius (75 degrees F). A standard residential type 7 kW air conditioning unit cools the air approximately 8 to 11 degrees celsius (15-20 degrees F) below ambient at a flow rate of .28 cubic meters per second (420 cfm). A forward curve blower provided .28 cubic meters per second of cooled air to the sows with a total preasure drop from the filter to the sows of 9 cm (3.5 in.) of water. The filter is a permanent type filter, which can be removed for periodic cleaning (figure 6).

A .36 m (14 in.) square cross section trunk duct, which is oriented the length of two farrowing rooms, 9.2 m

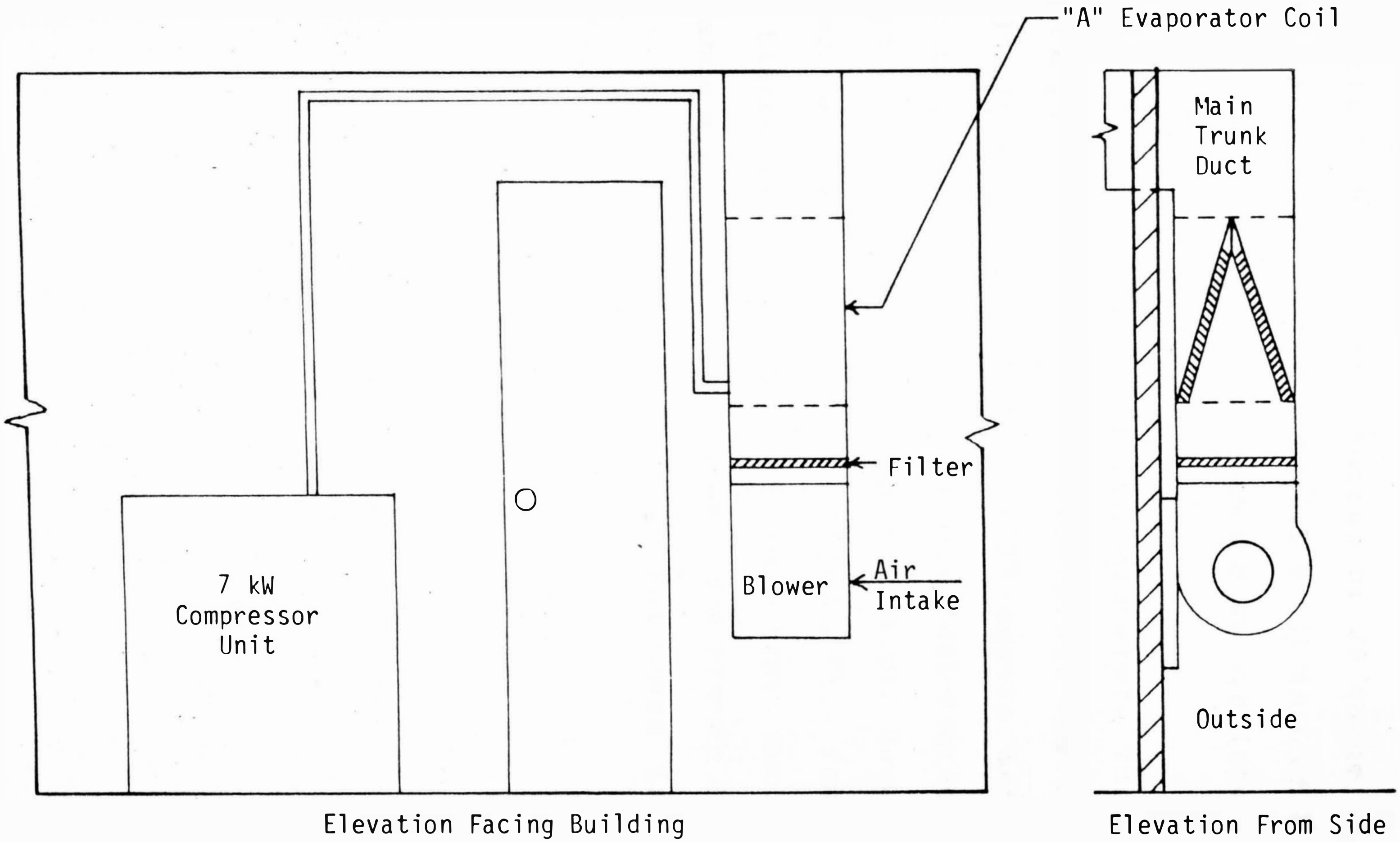

Figure 6. Snout cooling system schematic

(30 ft), delivered the cooled air to flexible branch ducts. This trunk duct is constructed of 26 gauge, galvanized steel and is insulated with 2.5 cm (1 in.) of fiberglass. A foil type duct liner provides a smooth interior surface for air flow.

Flexible, .1 m (4 in.) diameter, insulated duct with a polyethelene jacket, fiberglass insulation, and a foil type liner rated at .033 square meters-degrees celsius per Watt (.187 hours-square feet-degrees F per Btu) is permanently attached to the main trunk duct with a hose clamp. An adustable butterfly type baffle, installed where the branch duct attaches to the main trunk duct, is used to balance air flow to the crates. The branch duct to crate attachment is identical to that used in the snout ventilation system (figure 5).

RESULTS AND DISCUSSION

Swine Performance:

A snout cooling sytem, which delivered cooled air to 12 farrowing crates, was installed in two, six crate farrowing rooms and tested during the summers of 1982, 1983, and 1984. A snout ventilation system, which delivered outside air to six farrowing crates, was installed in one, six crate farrowing room and tested during the summers of 1983 and 1984. Both systems operated whenever the dry bulb temperatures in the farrowing rooms exceeded 24 degrees celsius (75 degrees F). Sows in three, six crate farrowing rooms served as controls during the summer of 1982 and sows in two, six crate farrowing rooms served as controls during the summers of 1983 and 1984.

Swine performance as affected by snout cooling and snout ventilation was tested by monitoring the following variables: sow weight loss during lactation, sow feed consumption during lactation, the number of days required for the sow to return to estrus after weaning, piglet death loss during lactation, weight gain of the piglets to seven days of age, and piglet weight gain during the entire lactation. Snout cooling and snout ventilation reduced sow weight loss during lactation, increased sow feed consumption during lactation, and reduced the time required for the sows to return to estrus after weaning, table 1. The sow performance variables as affected by parity group are listed in table 3 and the sow performance variables, within each of the three years, are listed in tables 2 and 4. Snout cooling reduced piglet death loss during lactation, decreased piglet weight gain to seven days of age, and increased overall piglet weight gain during the entire lactation, tables 5, 6, 7, and 8. Snout ventilation decreased piglet death loss during lactation for all three years and increased piglet weight gain to seven days of age during the summer of 1984, tables 5 and 8. The piglet performance variables as affected by parity group are listed in table 7 and the piglet performance variables, within each of the three years, are listed in tables 6, 8, and 9. Least squares means were used when comparing swine performance among treatments at the suggestion of Dr. Tucker (1985), Agricultural Experiment Station Statistician because of unequal subclass numbers (Steel and Torrie, 1980).

Environmental room temperature data were averaged for each 24 hour period from which degree-day values were calculated. The degree-day values were calculated by subtracting 24 degrees celsius (75 degrees F) from the 24 hour average room temperature, with negative values being set to zero. Analysis of variance of the degree-day values

Table 4. Sow weight loss, feed consumption and return to estrus during summers of 1982, 1983 and 1984

		Weight Loss (kg/day)			Feed Consumption (kg/day)			Days for Return of Estrus (3)		
	Summer	1982	1983	1984	1982	1983	1984	1982	1983	1984
Sample Group 1 (1)	Sample Size (sows)	96	37	54	107	38	73	105	35	65
	Least Squares Means	0.52	0.86	0.45	6.75	5.71	6.71	5.0	6.1	5.2
	Significance Levels (2)	A	B	A	A	B	A	a	a	a
Sample Group 2 (1)	Sample Size (sows)	65	37	46	65	38	65	64	35	58
	Least Squares Means	0.50	0.86	0.44	6.48	5.70	6.72	4.8	6.0	5.2
	Significance Levels (2)	A	B	A	A	B	A	a	a	a
Sample Group 3 (1)	Sample Size (sows)	30	37	30	30	38	40	30	35	36
	Least Squares Means	0.44	0.86	0.40	6.32	5.70	6.72	4.9	6.1	4.8
	Significance Levels (2)	A	B	A	A	B	A	a b	a	b

(1): Sample Group 1 consists of the entire collection of sows. Sample Group 2 consists of only sows which experienced 4 or more days with a minimum outside average temperature of 24 C. Sample Group 3 consists of only sows which experienced 3 or more days with a minimum outside average temperature of 27 C.

(2): Same letter designation indicates no significant difference between means. Capital letters represent significance at the 0.01 level, small letters represent significance at the 0.05 level.

(3): Indicates significant interaction effects of treatment and years.

Table 5. Effects of snout cooling and ventilation on piglet death loss, weight gain to seven days of age and overall weight gain

Sample Group (2)	Treatment (1)	Death Loss (pigs/litter)			Ave Daily Gain to Day 7 (kg/day) (4)			Ave Daily Gain to Weaning (kg/day)		
		Control	Fresh Air	AC	Control	Fresh Air	AC	Control	Fresh Air	AC
Sample Group 1 (2)	Sample Size (litters)	45	16	50	102	15	97	105	16	97
	Least Squares Means	0.97	0.85	0.91	0.16	0.16	0.16	0.20	0.20	0.21
	Significance Levels (3)	a	a	a	a	a	a	a	a b	b
Sample Group 2 (2)	Sample Size (litters)	43	16	44	83	15	68	84	16	68
	Least Squares Means	1.04	0.86	0.77	0.16	0.16	0.15	0.20	0.20	0.21
	Significance Levels (3)	a	a	a	a	a	a	a	a	a
Sample Group 3 (2)	Sample Size (litters)	33	16	29	50	15	41	51	16	41
	Least Squares Means	1.07	0.86	0.68	0.16	0.16	0.14	0.20	0.20	0.21
	Significance Levels (3)	a	a	a	a	a	a	A	A B	B

(1): Control refers to the control treatment, fresh air refers to the snout ventilation treatment, and AC refers to the snout cooling treatment.

(2): Sample Group 1 consists of the entire collection of litters. Sample Group 2 consists of only litters which experienced 4 or more days with a minimum outside average temperature of 24 C. Sample Group 3 consists of only litters which experienced 3 or more days with a minimum outside average temperature of 27 C.

(3): Same letter designation indicates no significant difference between means. Capital letters represent significance at the 0.01 level, small letters represent significance at the 0.05 level.

(4): Indicates significant interaction effects of treatments and years.

Table 6. Effects of snout cooling and ventilation on piglet weight gain to seven days of age within each year

Summer	Treatment (1)	Number of Litters	Gain per Piglet (kg/day)	Significane Levels (2)
1982	Control	58	0.16	a
1982	Fresh Air	0	----	---
1982	AC	47	0.18	b
1983	Control	12	0.17	a
1983	Fresh Air	7	0.14	a
1983	AC	18	0.15	a
1984	Control	32	0.17	a
1984	Fresh Air	8	0.19	a
1984	AC	32	0.16	a

(1): Control refers to the control treatment, fresh air refers to the snout ventilation treatment, and AC refers to the snout cooling treatment.

(2): Same letter designation indicates no significant difference between means. Capital letters represent significence at the 0.01 level, small letters represent significance at the 0.05 level.

Table 7. Effects of snout cooling, snout ventilation and parity group on piglet death loss, weight gain to seven days of age and overall weight gain during summer of 1984

	Piglet Death Loss (pigs/litter)			Piglet Ave Daily Gain to (2) Day 7 (kg/day)			Piglet Ave. Daily Gain to Weaning (kg/day)		
Treatment (1)	Control	Fresh Air	AC	Control	Fresh Air	AC	Control	Fresh Air	AC
Sample Size (litters)	32	10	32	32	8	32	32	10	32
Least Squares Means	1.08	1.21	1.05	0.16	0.20	0.15	0.19	0.20	0.20
Significance Levels (3)	a	a	a	a	a	a	a	a	a
Parity Group (4)	1	2	3	1	2	3	1	2	3
Sample Size (litters)	20	48	6	20	46	6	20	48	6
Least Squares Means	0.83	1.30	1.21	0.19	0.17	0.16	0.18	0.20	0.20
Significance Levels (3)	a	a	a	a	a	a	a	a	a

(1): Control refers to the control treatment, fresh air refers to the snout ventilation treatment, and AC refers to the snout cooling treatment.

(2): Indicates significant treatment/parity group interaction.

(3): Same letter designation indicates no significant differnce between means. Capital letters represent significance at the 0.01 level, small letters represent significance at the 0.05 level.

(4): Parity Group refers to the number of litters the sow has farrowed. Group 1 = first litter sows. Group 2 = second through seventh litter sows. Group 3 = eighth and up litter sows. Includes present litter.

Table 8. Effects of snout cooling and ventilation on piglet weight gain to seven days of age within each parity group for summer of 1984

Parity Group (1)	Treatment (2)	Number of Litters	Gain per Piglet (kg/day)	Significance Levels (3)	
1	Control	11	0.15	A	
1	Fresh Air	2	0.28		B
1	AC	7	0.14	A	
2	Control	17	0.18	a	
2	Fresh Air	6	0.16	a	
2	AC	23	0.16	a	
3	Control	4	0.15	a	
3	Fresh Air	0	----	---	
3	AC	2	0.15	a	

(1): Parity Group refers to the number of litters the sow has farrowed. Group 1 = first litter sows. Group 2 = second through seventh litter sows. Group 3 = eighth and up litter sows. Includes present litter.

(2): Control refers to the control treatment, fresh air refers to the snout ventilation treatment, and AC refers to the snout cooling treatment.

(3): Same letter designation indicates no significant difference between means. Capital letters represent significence at the 0.01 level, small letters represent significance at the 0.05 level.

Table 9. Piglet death loss, weight gain to seven days of age and overall weight gain during summers of 1982, 1983 and 1984

		Death Loss (pigs/litter)			Ave Daily Gain to Day 7 (kg/day) (3)			Ave Daily Gain to Weaning (kg/day)		
	Summer	1982	1983	1984	1982	1983	1984	1982	1983	1984
Sample Group 1 (1)	Sample Size (litters)	0	38	73	105	37	72	107	38	73
	Least Squares Means	--	0.73	1.09	0.17	0.15	0.17	0.21	0.20	0.20
	Significance Levels (2)		a	a	a	a	a	a	a	a
Sample Group 2	Sample Size (litters)	0	38	65	65	37	64	65	38	65
	Least Squares Means	--	0.75	1.03	0.15	0.16	0.16	0.20	0.20	0.20
	Significance Levels (2)		a	a	a	a	a	a	a	a
Sample Group 3 (1)	Sample Size (litters)	0	38	40	30	37	39	30	38	40
	Least Squares Means	--	0.76	0.98	0.14	0.16	0.17	0.19	0.20	0.21
	Significance Levels (2)		a	a	A	A B	B	a	a	a

(1): Sample Group 1 consists of the entire collection of litters. Sample Group 2 consists of only litters which experienced 4 or more days with a minimum outside average temperature of 24 C. Sample Group 3 consists of only litters which experienced 3 or more days with a minimum outside average temperature of 27 C.

(2): Same letter designation indicates no significant difference between means. Capital letters represent significance at the 0.01 level, small letters represent significance at the 0.05 level.

(3): Indicates significant interaction effects of treatments and years.

indicated that the environmental room temperatures were treatment dependent. Therefore, the environmental room temperature data were not used in the analysis of the swine performance variables, except for sow respiration rates. The snout cooling system, when operating, typically lowered the environmental room air temperatures by .5 to 1 degree celsius (1-2 degrees F) compared to the control and snout ventilated rooms.

Climatic dry bulb temperature data from the National Weather Service at Sioux Falls, South Dakota for three hour periods were used to determine daily average outside temperatures, since the environmental room temperature data were found to be treatment dependent. There were 148 sows and litters that experienced at least four days with an average outside temperature of 24 degrees celsius (75 degrees F), or higher. Seventy one of these experienced at least three days with an average outside temperature of 27 degrees celsius (80 degrees F), or higher. The effects of snout cooling and snout ventilation were separately tested on the three sets of data: all sows and litters, the 148 sow and litter subset, and the 71 sow and litter subset.

Average daily sow weight loss during lactation was slightly less for the sows of the snout cooled and the snout ventilated groups with averages of .63 kg/day (1.4

lb/day) for the control group, .61 kg/day (1.3 lb/day) for the snout ventilated group, and .59 kg/day (1.3 lb/day) for the snout cooled group (table 1, 3, and 4). Therfore, snout cooling reduced sow weight loss during lactation by six percent and snout ventilation reduced sow weight loss during lactation by three percent. However, these reductions were nonsignificant.

The snout systems resulted in increased sow feed consumption during lactation. The daily sow feed consumption averages for the control groups, snout ventilated groups, and snout cooled groups were respectively: 6.24 kg/day (13.8 lb/day), 6.36 kg/day (14 lb/day), and 6.56 kg/day (14.5 lb/day) for all sows; 6.12 kg/day (13.5 lb/day), 6.27 kg/day (13.8 lb/day), and 6.52 kg/day (14.4 lb/day) for those sows that experienced at least four days of 24 degrees celsius (75 degrees F), or higher average outside temperature; 6.01 kg/day (13.2 lb/day), 6.22 kg/day (13.7 lb/day), and 6.51 kg/day (14.4 lb/day) for those sows that experienced at least 27 degrees celsius (80 degrees F), or higher average outside temperature (table 1).

Snout cooling increased average daily sow feed consumption during lactation by five percent for the entire collection of sows, six percent for those sows that experienced at least four days of 24 degrees celsius (75 degrees F), or higher average outside temperature, and eight percent for those sows that experienced at least three days of 27 degrees celsius (80 degrees F), or higher average outside temperature (table 1). All of the increases in sow feed consumption due to snout cooling are statistically significant. Snout ventilation increased average daily sow feed consumption by two percent for the entire collection of sows, two percent for those sows that experienced at least four days of 24 degrees celsius (75 degrees F), or higher average outside temperature, and four percent for those sows that experienced at least three days of 27 degrees celsius (80 degrees F), or higher average outside temperature. This suggests that the effects of the snout systems on sow feed consumption increase as climatic temperatures increase. The snout ventilation system increased sow feed consumption, however, all of these increases were nonsignificant (table 1).

The effect of parity group on sow feed consumption was found to be highly significant, with first litter sows consuming significantly less feed per day than older sows (table 3). Parity group 1 consisted of those sows which were nursing their first litter, parity group 2 were those sows which were nursing their second through seventh litter, and parity group 3 consisted of the remaining sows from the summer of 1984.

The snout systems reduced the number of days required for the sows to return to estrus after weaning with snout cooling reducing this time period by .7 days and snout ventilation reducing this time period by .1 days for the entire collection of sows (table 1). Treatments and years interacted at a significant level to affect the days required for the sow to return to estrus. The snout cooled sows required an average of 4.8 days to return to estrus, which was significantly less than the average number of days required by the control group, 7.6 days, during the summer of 1983. Therefore, snout cooling reduced this time period by 2.8 days during the summer of 1983 (table 2).

The snout systems reduced piglet death loss during lactation. Average piglet death loss per litter during lactation was .97 for the control group, .85 for the snout ventilated group, and .91 for the snout cooled group for the entire collection of litters (table 5). Average piglet death loss per litter during lactation for those litters that experienced at least three days with an average outside temperature of 27 degrees celsius (80 degrees F), or higher, was 1.07 for the control group, .86 for the snout ventilated group, and .68 for the snout cooled group (table 5). However, all differences were nonsignificant. These differences may have been more pronounced, if death loss data would have been available for the first summer.

Piglet average daily weight gain to seven days of age was lower for the piglets of the snout cooled group compared to the average of the control group when the data for all three years was combined (table 5). These effects become more apparent when comparisons are made for litters which experienced at least three days with an average outside temperature of 27 degrees celsius (80 degrees F), or higher (table 5). This may be due to additional drafts being produced by the snout systems. However, snout cooling increased average piglet weight gain to seven days of age by .02 kg/day (.04 lb/day), 12 percent, during the summer of 1982 (table 6). Snout ventilation had no detectable effect on average piglet weight gain to seven days of age while, overall, snout cooling reduced average piglet weight gain to seven days of age by six percent for those piglets that experienced at least four days of 24 degrees celcius (75 degrees F), or higher average outside temperature and 12 percent for those piglets that experienced at least three days of 27 degrees celsius (80 degrees F), or higher average outside temperature. All reductions were nonsignificant.

Piglet average daily weight gain to seven days of age for the snout ventilated group was significantly greater than that of the snout cooled or control groups when considering sows which were nursing their first litter (table 8). The combined effects of the snout systems and sow age on the average daily gain of the piglets to age seven days was significant. Despite the statistical significance, note that there were only two samples in the snout ventilated group in this case. Care should be taken because of the small number of litters involved.

Average daily gains of the piglets during the entire lactation were significantly higher for the snout cooled group compared to the control group (table 5). This difference becomes more apparent when comparisons are made among treatments for samples that experienced at least three days of 27 degrees celsius (80 degrees F), or higher, average outside temperature (table 5), which would indicate that the effects of snout cooling on overall piglet weight gain increase as climatic temperatures increase. Snout cooling increased overall daily piglet weight gain during lactation by five percent.

Respiration rates of the sows were significantly lowered by the snout systems, indicating improved sow comfort (Appendix A). Data for the sow respiration rates are represented in figures 7 through 9. The resulting multiple regression curves are compared in figure 10. Only sow respiration rates taken at environmental room temperatures of 27 degrees celsius (80 degrees F), or higher, were considered. The resulting regression

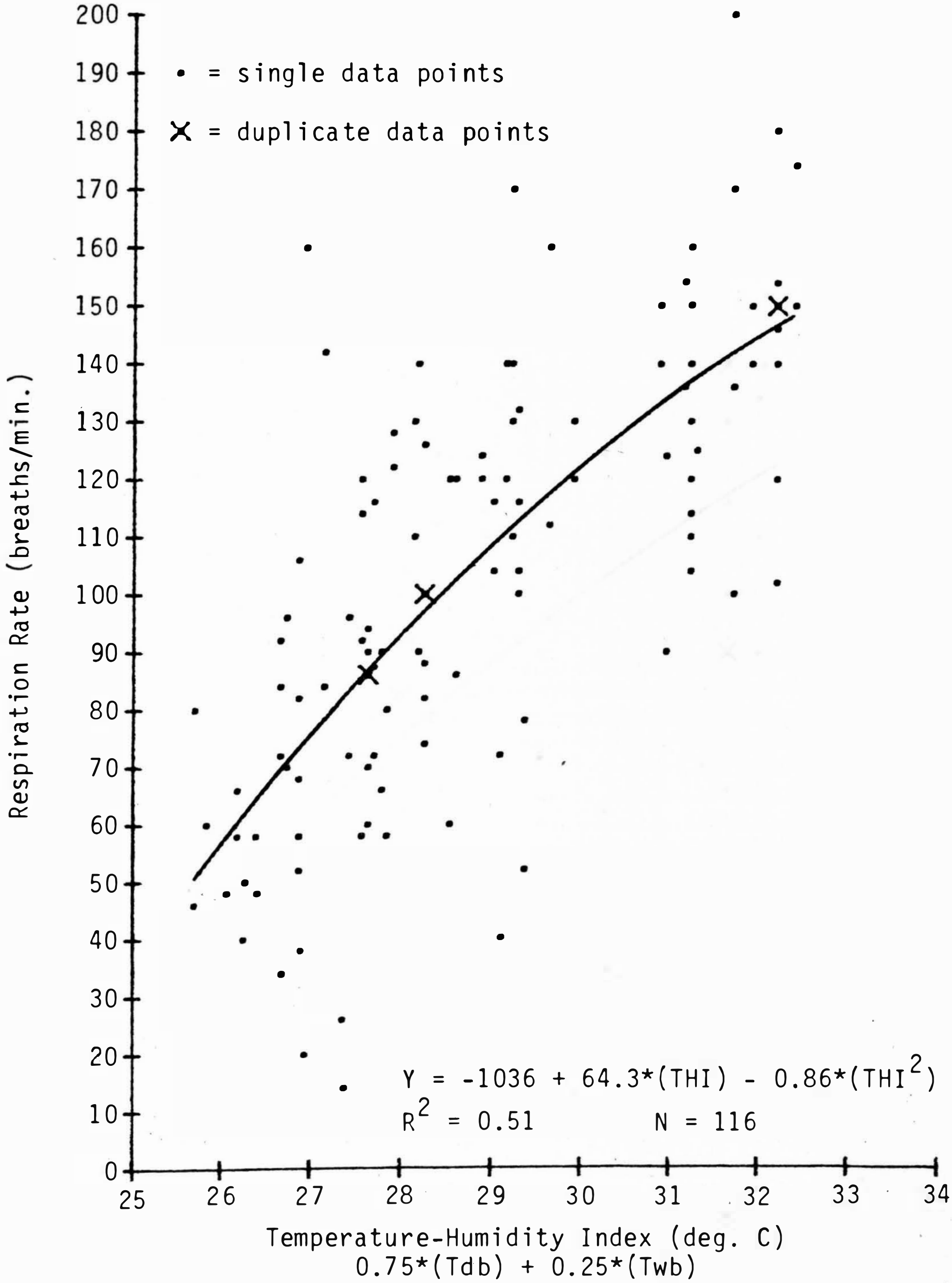

Figure 7. Sow respiration rate as influenced by temperature-humidity index for control group

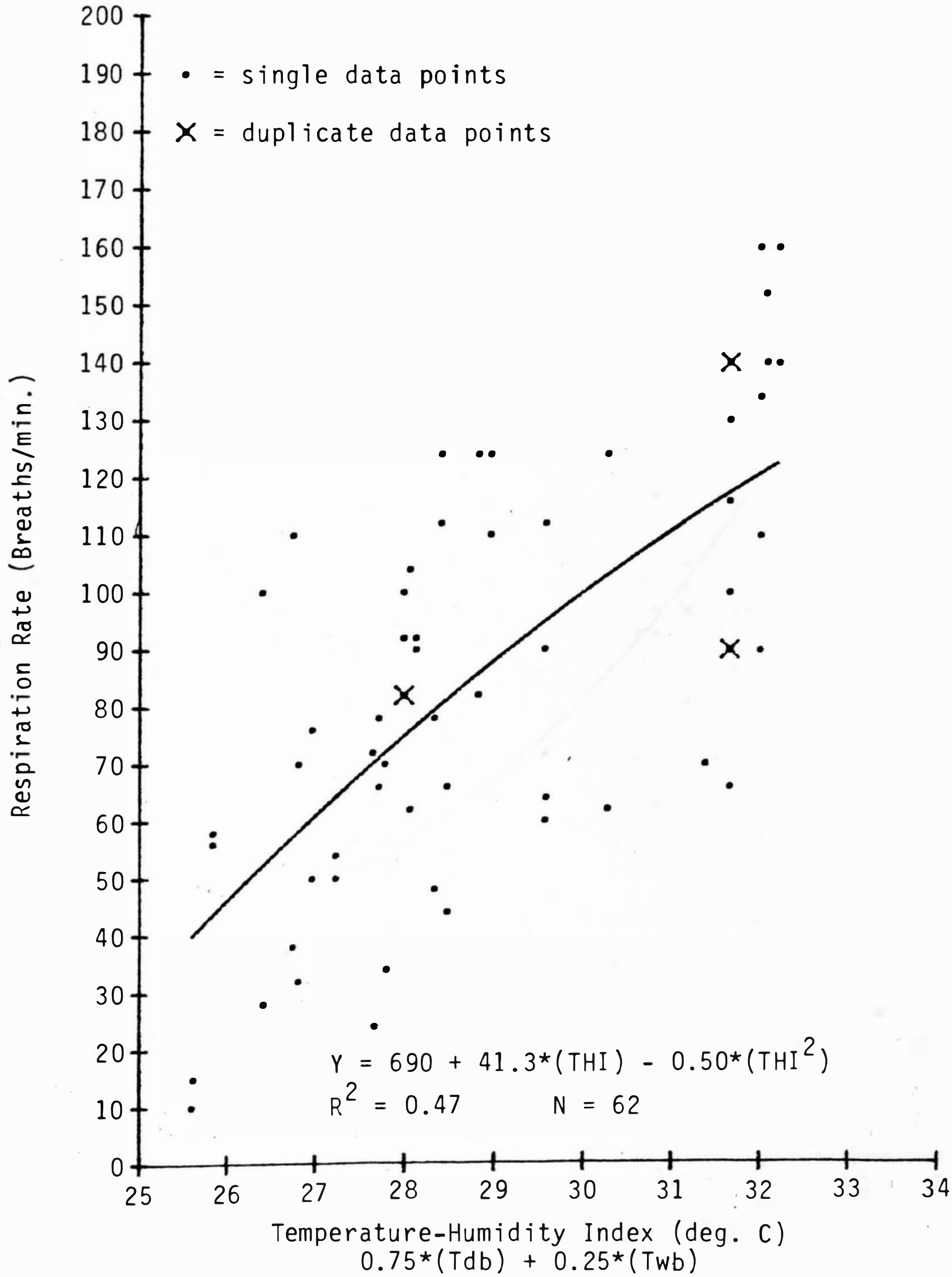

Figure 8. Sow respiration rate as influenced by temperature-humidity index for snout ventilated group

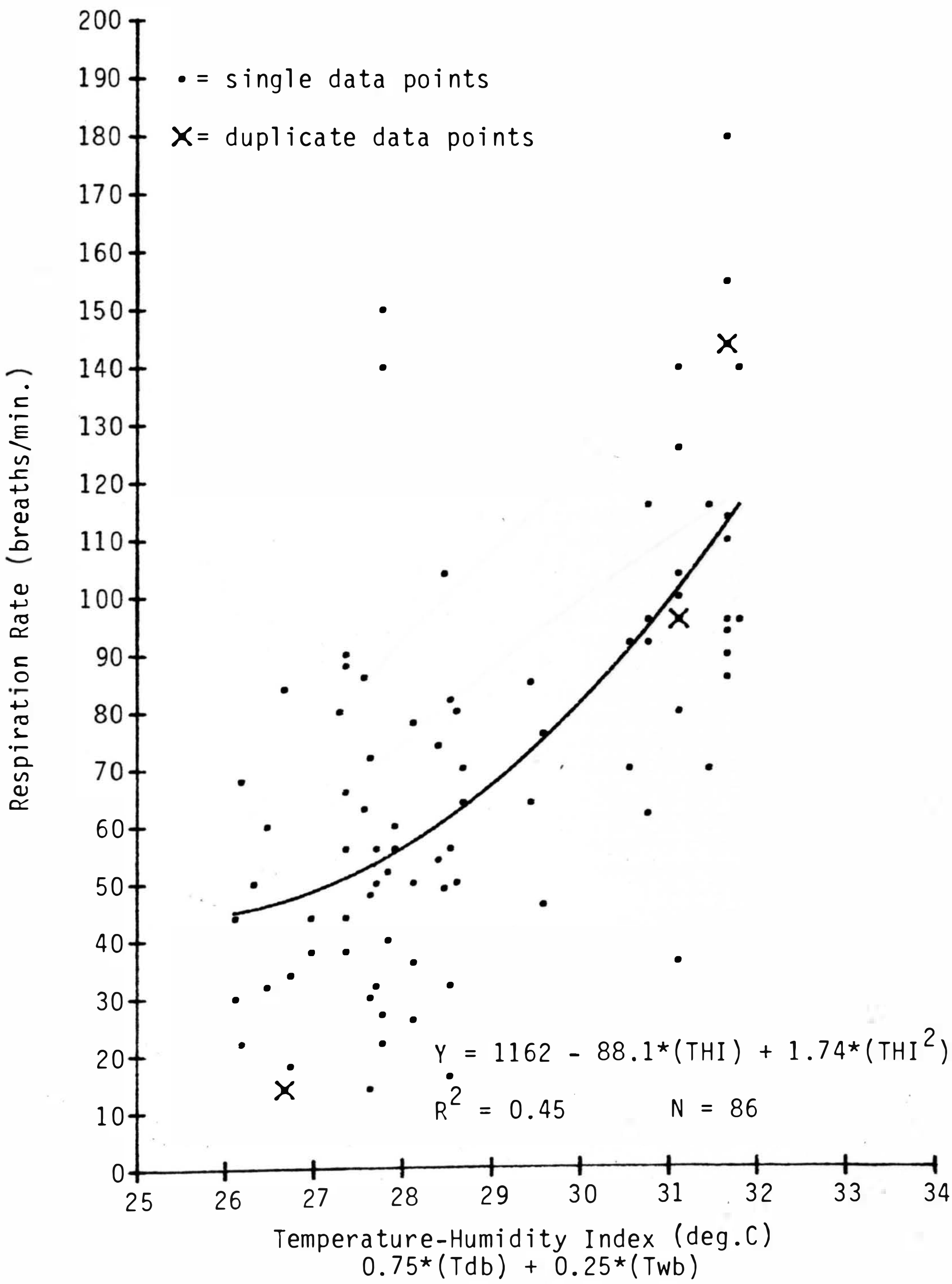

Figure 9. Sow respiration rate as influenced by temperature-humidity index for snout cooled group

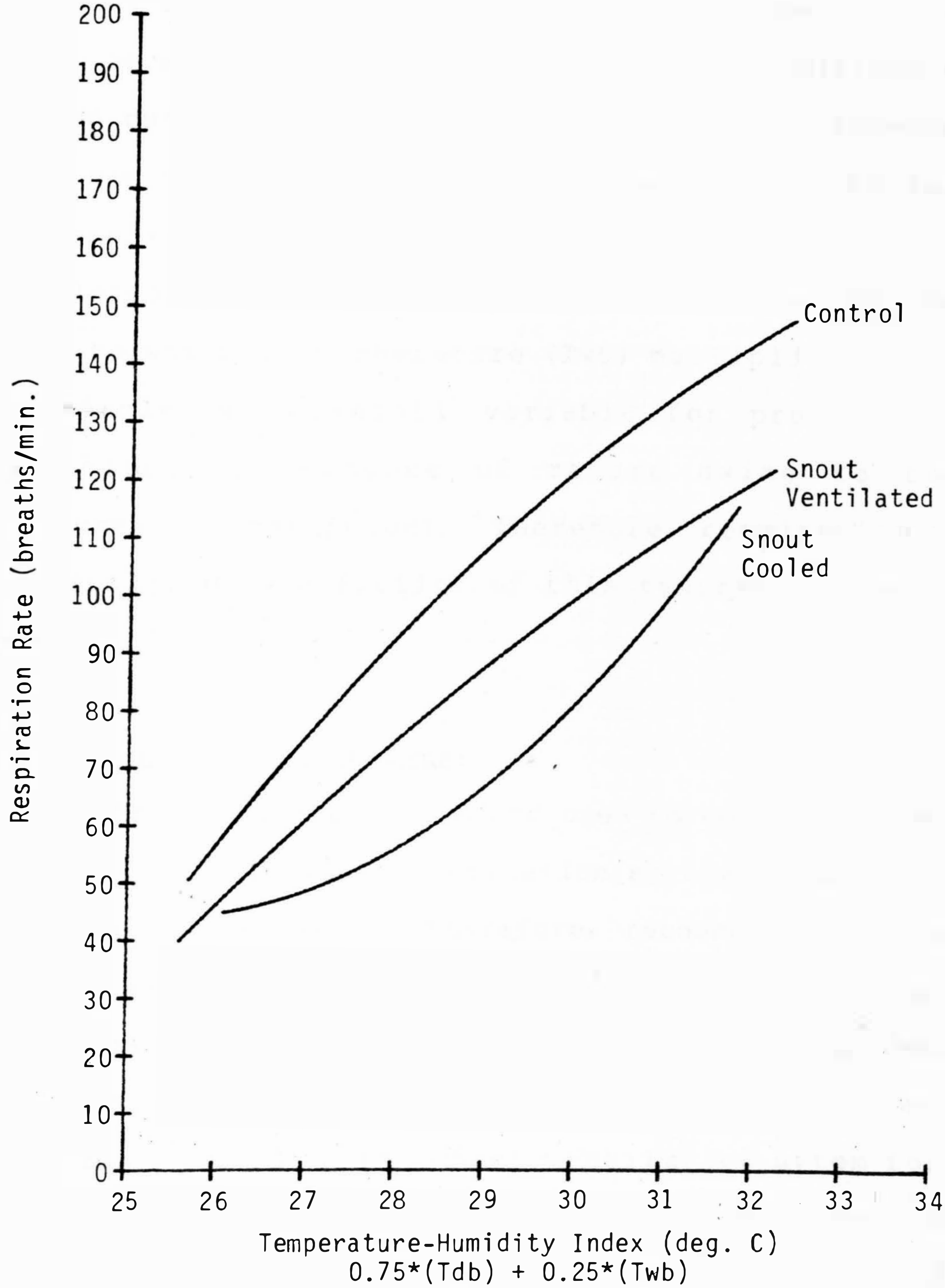

Figure 10. Sow respiration rate as influenced by temperature-humidity index

equations should not be used for predicting sow respiration rates, because they represent the specific conditions which existed during this investigation and are only intended to represent the conditions of this investigation. Roller and Goldman (1969) defined a temperature-humidity index calculated by multiplying dry bulb temperature (Tdb) by .75 added to wet bulb temperature (Twb) multiplied by .25 as the single best overall variable for predicting the physiological response of mature swine to summer environmental conditions. Therefore, respiration rates were analyzed as a fuction of this temperature-humidity index.

Evaluation of Sytem Designs:

The insulated duct board used to construct the main trunk duct for the snout ventilation system performed well. Insulated duct board is, therefore, recommended instead of the more expensive 26 gauge, galvanized steel ducting with fiberglass insulation used in the snout cooling system.

Some problems were encountered with the flexible dryer tubing used in the snout ventilation sytem for the branch ducts. Failure is caused when the PVC pipe, which is fastened to the flexible tubing, is dropped while removing the branch duct from the front of the farrowing crate, producing tension in the tubing. Therefore, the more expensive flexible tubing like that used in the snout cooling system is recommended.

Airflows of the two sytems in the branch ducts remained relatively constant throughout each summer. Slight adjustments of the butterfly type baffles were required at the beginning of each summer. The butterfly type baffles used in these sytems are quite sensitive and are difficult to adjust. A different type of baffle, preferably of sliding plate type located near the branch duct outlet, is recommended. This would make adjustments easier with the operator able to position the plate while simultaneously checking the airflow.

The PVC pipe used to direct the airflow toward the sow's head area was not subject to damage by the sows. However, a different arrangement to introduce the airflow to the sow nose area is recommended to minimize draft on the young piglets and to provide airflow to the sow nose area while the sow is lying down in the crate.

Observations revealed that the trunk duct in this facility altered the airflow patterns of the conventional summer ventilation system. It is recommended that the main trunk duct be moved to the attic to avoid interference with the normal ventilation airflow patterns. The incoming stream of ventilation air was deflected downward into the farrowing crates on the north side of the rooms. The air velocity in the farrowing crates on the south side of the farrowing rooms was reduced (figures 2, 3, and 4). No effect was detected on the conventional winter ventilation airflow patterns.

Estimated electrical operating costs of the snout cooling system is $.80 per day. This is based on an electrical rate of $.04/kW-h, an operating voltage of 220 volts, and on amperage data collected over a total period of 139 days, 62 days in the summer of 1983 and 77 days in the summer of 1984. This operating cost estimate should be fairly typical due to the climatic temperatures experienced during data collection. Table C.3 summarizes climatic temperature data for Sioux Falls, South Dakota for the appropriate months of 1983 and 1984.

Recommendations for future snout cooling research include developing an outlet for the snout systems that would minimize drafts on the young piglets and provide airflow to the sow while she is lying down in the farrowing crate and also determining the optimal airflow rate for such snout systems. Additional research might also include evaluating the possibility of cooling the air with tubes located beneath the ground and developing a switch to allow the sow to activate the snout system when desired.

CONCLUSIONS

The results of this investigation support the following conclusions.

1. Snout cooling reduced sow weight loss during lactation by six percent and snout ventilation reduced sow weight loss during lactation by three percent. All reductions were nonsignificant.

2. Snout cooling increased sow feed consumption by five percent for the entire collection of sows and eight percent for those sows that experienced at least three days of 27 degrees celsius (80 degrees F), or higher average outside temperature. Snout ventilation increased sow feed consumption by two percent for the entire collection of sows and four percent for those sows that experienced at least three days of 27 degrees celsius (80 degrees F), or higher average outside temperature.

3. The snout cooling and snout ventilation systems resulted in a shorter amount of time required for the sows to return to estrus after weaning. Snout cooling reduced this time period by .7 days and snout ventilation reduced this time period by .1 days. However, these reductions were nonsignificant. Snout cooling reduced this time period by 2.8 days during the summer of 1983.

4. Snout cooling reduced piglet death loss during lactation with the control group averaging .97 deaths per litter, the snout ventilated group averaging .85 deaths per litter, and the snout cooled group averaging .91 deaths per litter.

5. The effects of the snout cooling and snout ventilation systems were small, if any, on piglet average daily weight gain to seven days of age for the entire data set while snout cooling reduced piglet weight gain to seven days of age by 12 percent for those litters which experienced higher climatic temperatures. However, this reduction was nonsignificant.

6. Snout cooling increased piglet average daily weight gain during lactation by five percent while snout ventilation had no noticeable effects.

7. Snout cooling and snout ventilation reduced sow respiration rates, where snout cooling resulted in the largest reduction, indicating increased sow comfort due to the snout systems.

8. Estimated electrical operating cost of the snout cooling system is $.80 per day for the 12 crate system. The snout cooling system lowered the environmental room air temperatures by an average of .4 degrees celsius.

9. The insulated duct board used in the snout ventilation system should be used instead of the 26 qauge galvinized steel ducting used in the snout cooling system for construction of the main trunk duct since it is durable enough and more economical.

10. The insulated flexible tubing used to construct the branch ducts of the snout cooling system should be used instead of the conventional plastic dryer tubing used for the snout ventilation system because of its greater durability.

SUMMARY

Decreased swine performance has been attributed to heat stress. Sows and young piglets do not acheive maximum performance at the same environmental conditions. Therefore, research was conducted to investigate the effects of snout ventilation and snout cooling on the performance of swine during the farrowing and lactation period in a commercial confinement farrowing facility.

Effects of three treatments: snout ventilation plus conventional ventilation, snout cooling plus conventional ventilation, and conventional ventilation only, on swine performance were compared. The snout ventilation system delivered .034 cubic meters per second (70 cfm) of outside to the sow nose area and the snout cooling system delivered .017 cubic meters per second (35 cfm) of mechanically refrigerated air to the sow nose area.

Results indicated improved swine performance due to the snout systems. The snout ventilation system lowered sow respiration rates compared to the control group. The snout cooling system resulted in increased sow feed consumption and increased overall piglet weight gain during lactation with greater differences among the three groups resulting during periods of higher climatic temperatures. However, the snout cooling system appeared to have produced unwanted drafts in the piglet area, which may have reduced average

daily gain of the piglets to seven days of age. Sow respiration rates were significantly lowered by the snout cooling system. Estimated electrical operating cost of the snout cooling system is $.80 per day for the 12 crate system.

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APPENDICES

APPENDIX A: Statistical techniques used to analyze the effects of the snout systems on sow respiration rates.

Respiration rates were compared among the three treatments and regression curves developed. Three separate tests were made based on statistical techniques described by Scheaffer and McClave (1982).

In Case I the regression curves for the respiration rates of the snout ventilated sows was compared to that of the control sows. The samples of the control group were assigned a zero and the samples of the snout ventilated group were assigned a one, referred to as a dummy variable, in order to distinghish between the two groups. The two populations were then combined and a multiple regression analysis performed without the dummy variable. The equation for the reduced model and the sum of squared errors (SSE_1) was obtained.

The multiple regression analysis was then repeated with the dummy variable, which resulted in twice the number of beta parameters. The equation for the full model and the corresponding sum of squared errors (SSE_2) was then obtained. Next, an F value was calculated by the following equation where N equals population size.

$$F = ((SSE_1 - SSE_2) / 3) / (SSE_2 / N - 6)$$

The null hypothesis is that all of the beta parameters which correspond with the dummy variable are equal to zero with the alternate hypothesis being that at least one of the beta parameters under test is nonzero.

The preceeding procedure was conducted similarly for each of the other two comparisons, snout cooled compared to control and snout ventilated compared to snout cooled.

Case 1. Snout Ventilated Sows compared to Control Sows

Reduced Model:

$$E(Y)^{*} = -1013 + 63.1*(THI) - 0.85*(THI^2)$$

$$SSE_1 = 142{,}441 \qquad R_2 = 0.47$$

$$N = 178$$

Full Model:

$$\begin{aligned} E(Y)^{*} &= -1036 + 64.3*(THI) - 0.86*(THI^2) \\ &+ 345*X - 23.0*X*(THI) + 0.36*X*(THI^2) \end{aligned}$$

where: $X = 1$; if snout ventilated sow
$= 0$; if control sow

$$SSE_2 = 127{,}300 \qquad R^2=0.52$$

Test Statistic:

$$\begin{aligned} F &= ((\ 142{,}441 - 127{,}300\ )/\ 3\ )/((\ 127{,}300\ /(\ 178 - 6\ )) \\ &= 6.82 \end{aligned}$$

$$F = 6.82 > F^{3}_{172}(0.01)$$

Therefore, the regression curve for the respiration rates of the snout ventilated sows is significantly different than that of the control sows at the 0.01 level.

* E(Y) represents the expected value of the respiration rates for the sows.

Case 2. Snout Cooled Sows compared to Control Sows

Reduced Model:

$$E(Y)^{*} = -88 - 1.4*(THI) + 0.26*(THI^2)$$

$$SSE_1 = 201{,}244 \qquad R^2 = 0.41$$

$$N = 202$$

Full Model:

$$E(Y)^{*} = -1036 + 64.3*(THI) - 0.86(THI^2) + 2{,}197*X - 152.4*X*(THI) + 2.59*X*(THI^2)$$

where: $X = 1$; if snout cooled sow
$= 0$; if control sow

$$SSE_2 = 148{,}438 \qquad R^2 = 0.57$$

Test Statistic:

$$F = ((201{,}244 - 148{,}438)/3)/(148{,}438/(202 - 6)) = 23.24$$

$$F = 23.24 > F^{3}_{196}(0.01)$$

Therefore, the regression curve for the respiration rates of the snout cooled sows is significantly different than that of the control sows at the 0.01 level.

* E(Y) represents the expected value of the respiration rates of the sows.

Case 3. Snout Ventilated Sows compared to Snout Cooled Sows

Reduced Model:

$$E(Y)^{*} = 260 - 25.3*(THI) + 0.65*(THI^{2})$$

$$SSE_1 = 114,190 \qquad R^2 = 0.45$$

$$N = 148$$

Full Model:

$$E(Y)^{*} = -690 + 41.3*(THI) - 0.50*(THI^{2}) + 1852*X - 129.4*X*(THI) + 2.24*X*(THI^{2})$$

where: X = 1; if snout cooled sow
= 0; if snout ventilated sow

$$SSE_2 = 106,789 \qquad R^2 = 0.48$$

Test Statistic:

$$F = ((114,190 - 106,789)/ 3)/(106,789 /(148 - 6)) = 3.28$$

$$F = 3.28 > F^{3}_{142}(0.05)$$

Therefore, the regression curve for the respiration rates of the snout cooled sows is significantly different than that of the snout ventilated sows at the 0.05 level.

* E(Y) represents the expected value of the respiration rates of the sows.

Appendix B: Sow Respiration Rates and Corresponding Room Temperatures

Table B.1. Respiration rates of control sows and corresponding room temperatures

Resp. Rate	Tdb	Twb	Resp. Rate	Tdb	Twb (1)
170	91.0	80.5	125	91.0	80.5
146	93.0	81.0	150	93.0	81.0
102	93.0	81.0	120	93.0	81.0
150	93.0	81.0	140	93.0	81.0
154	93.0	81.0	180	93.0	81.0
124	90.5	79.5	90	90.5	79.5
140	91.0	80.0	110	91.0	80.0
114	91.0	80.0	160	91.0	80.0
130	91.0	80.0	104	91.0	80.0
150	91.0	80.0	120	91.0	80.0
136	92.0	80.5	100	92.0	80.5
110	85.0	75.7	130	85.0	75.7
130	88.5	78.0	120	88.5	78.0
150	92.5	80.5	140	92.5	80.5
174	94.0	79.5	150	94.0	79.5
86	84.0	75.0	90	84.0	75.0
170	87.0	77.5	110	87.0	77.5
150	90.0	80.5	140	90.0	80.5
170	92.0	80.5	200	92.0	80.5
14	83.0	76.0	26	83.0	76.0
100	87.0	78.0	116	87.0	78.0
84	82.5	76.0	142	82.5	76.0
124	86.0	78.0	120	86.0	78.0
112	88.0	77.5	160	88.0	77.5
154	92.0	76.5	136	92.0	76.5
66	81.0	73.5	58	81.0	73.5
78	88.0	75.5	52	88.0	75.5
40	87.0	76.5	72	87.0	76.5
80	80.0	73.0	46	80.0	73.0
128	85.0	74.0	122	85.0	74.0
130	88.0	74.5	120	83.5	76.0
114	83.5	76.0	92	83.5	76.0
58	83.5	76.0	86	84.0	75.0
70	84.0	75.0	126	86.0	73.5
82	86.0	73.5	48	82.0	72.0

(1): Respiration rates are in breaths per minute and temperatures are in degrees fahrenheit.

Table B.1. continued

Resp. Rate	Tdb	Twb	Resp. Rate	Tdb	Twb (1)
58	82.0	72.0	52	83.0	72.5
82	83.0	72.5	58	85.0	73.5
80	85.0	73.5	88	86.0	73.5
74	86.0	73.5	100	86.0	73.5
100	86.0	73.5	116	88.0	73.0
104	88.0	73.0	120	88.0	74.0
140	88.0	74.0	104	88.5	73.5
132	88.5	73.5	60	81.0	71.0
48	81.5	71.0	40	82.0	71.0
50	82.0	71.0	68	83.0	72.5
106	83.0	72.5	96	84.5	72.0
72	84.5	72.0	72	85.0	72.5
116	85.0	72.5	60	87.0	72.5
120	87.0	72.5	90	86.0	73.0
140	86.0	73.0	86	87.0	73.0
120	87.0	73.0	140	88.0	74.5
72	81.5	75.5	92	81.5	75.5
70	81.5	76.0	96	81.5	76.0
84	81.5	75.5	34	81.5	75.5
160	82.0	76.0	20	82.0	76.0
58	83.5	71.0	38	83.5	71.0
94	85.0	72.0	60	85.0	72.0
90	85.2	72.5	66	85.2	72.5

(1): Respiration rates are in breaths per minute and temperatures are in degrees fahrenheit.

Table B.2. Respiration rates of snout ventilated sows and corresponding room temperatures

Resp. Rate	Tdb	Twb	Resp. Rate	Tdb	Twb (1)
92	91.5	79.5	70	91.5	79.5
140	92.0	80.0	90	92.0	80.0
130	92.0	80.0	100	92.0	80.0
90	92.0	80.0	66	92.0	80.0
116	92.0	80.0	104	85.0	75.0
62	85.0	75.0	124	89.0	79.0
62	89.0	79.0	110	92.5	81.0
160	92.5	81.0	140	93.0	80.0
152	93.0	80.0	34	84.0	76.0
70	84.0	76.0	82	86.0	77.5
124	86.0	77.5	64	88.0	77.0
112	88.0	77.0	160	94.5	76.5
140	94.5	76.5	140	92.0	80.0
134	93.0	79.5	90	93.0	79.5
82	85.0	74.5	82	85.0	74.5
56	81.0	71.0	58	81.0	71.0
70	83.0	72.0	54	84.0	72.0
32	83.0	72.0	50	84.0	72.0
72	85.0	72.0	24	85.0	72.0
100	86.0	71.5	92	86.0	71.5
44	87.0	72.0	66	87.0	72.0
112	87.0	71.5	124	87.0	71.5
124	88.0	72.5	110	88.0	72.5
10	80.0	72.3	15	80.0	72.3
48	86.0	74.0	78	86.0	74.0
60	88.8	74.5	90	88.8	74.5
28	81.0	75.0	100	81.0	75.0
38	81.5	76.0	110	81.5	76.0
76	83.8	70.7	50	83.8	70.7
66	85.0	72.5	78	85.0	72.5
90	86.0	72.5	92	86.0	72.5

(1): Respiration rates are in breaths per minute and temperatures are in degrees fahrenheit.

Table B.3. Respiration rates of snout cooled sows and corresponding room temperatures

Resp. Rate	Tdb	Twb	Resp. Rate	Tdb	Twb (1)
96	91.0	79.0	96	91.0	79.0
36	91.0	79.0	104	91.0	79.0
126	91.0	79.0	140	91.0	79.0
100	91.0	79.0	80	91.0	79.0
116	90.0	79.5	92	90.0	79.5
144	92.0	80.0	86	92.0	80.0
96	92.0	81.0	140	92.0	81.0
94	92.0	80.0	110	92.0	80.0
96	92.0	80.0	144	92.0	80.0
90	92.0	80.0	180	92.0	80.0
74	85.5	76.0	54	85.5	76.0
96	90.0	79.5	62	90.0	79.5
92	90.0	78.0	70	90.0	78.0
14	81.5	75.5	14	81.5	75.5
32	85.5	77.0	85	87.5	77.5
16	85.5	77.0	64	87.5	77.5
116	92.5	77.0	70	92.5	77.0
46	88.0	77.0	76	88.0	77.0
114	93.0	77.0	155	93.0	77.0
52	84.8	74.0	40	84.8	74.0
104	86.0	75.0	49	86.0	75.0
86	84.0	74.5	63	84.0	74.5
88	83.5	74.5	90	83.5	74.5
44	83.5	74.5	56	83.5	74.5
84	82.0	74.0	140	85.0	73.0
150	85.0	73.0	22	85.0	73.0
27	85.0	73.0	30	81.0	73.0
44	81.0	73.0	18	83.0	71.5
34	83.0	71.5	30	85.0	72.0
14	85.0	72.0	50	85.0	72.5
32	85.0	72.5	50	86.0	72.5
36	86.0	72.5	80	87.0	73.0
50	87.0	73.0	56	87.0	72.5
82	87.0	72.5	70	87.5	72.0
64	87.5	72.0	56	84.0	75.5

(1): Respiration rates are in breaths per minute and temperatures are in degrees fahrenheit.

Table B.3. continued

Resp. Rate	Tdb	Twb	Resp. Rate	Tdb	Twb (1)
80	83.0	75.5	50	81.0	74.5
68	80.5	75.0	22	80.5	75.0
60	82.8	70.2	32	82.8	70.2
38	84.5	71.5	66	84.5	71.5
60	85.5	72.5	56	85.5	72.5
38	84.0	70.2	44	84.0	70.2
72	85.0	72.0	48	85.0	72.0
78	86.0	72.5	26	86.0	72.5

(1): Respiration rates are in breaths per minute and temperatures are in degrees fahrenheit.

APPENDIX C: Electrical Usage Data for Compressor Unit

Table C.1. Electrical usage of the compressor unit for the Summer of 1983

Date	Hours of Operation	Kilowatt Hours
7/29/83	21.0	40.0
7/30/83	15.9	28.4
7/31/83	12.8	23.8
8/01/83	16.0	29.2
8/02/83	17.8	37.3
8/03/83	24.0	47.9
8/04/83	19.1	38.7
8/05/83	24.0	46.2
8/06/83	22.1	42.0
8/07/83	17.1	33.8
8/08/83	17.5	34.6
8/09/83	15.1	29.8
8/10/83	22.3	43.8
8/11/83	10.0	18.3
8/12/83	14.2	26.9
8/13/83	12.0	23.2
8/14/83	15.3	28.7
8/15/83	24.0	48.1
8/16/83	24.0	48.0
8/17/83	18.3	35.5
8/18/83	15.6	35.7
8/19/83	21.8	43.3
8/20/83	15.3	30.3
8/21/83	16.1	32.9
8/22/83	14.2	26.1
8/23/83	24.0	44.3
8/24/83	23.9	44.8
8/25/83	24.0	47.8
8/26/83	9.0	16.7
8/27/83	18.3	34.5
8/28/83	17.9	37.1
8/29/83	9.5	17.2
8/30/83	13.3	25.5
8/31/83	11.8	22.4
9/01/83	14.8	31.4
9/02/83	15.7	33.0
9/03/83	0.6	1.0
9/04/83	0.0	0.0
9/05/83	0.0	0.0
9/06/83	0.0	0.0
9/07/83	3.4	7.3
9/08/83	0.0	0.0

Table C.1. continued

Date	Hours of Operation	Kilowatt Hours
9/09/83	0.0	0.0
9/10/83	2.6	4.1
9/11/83	8.2	13.6
9/12/83	0.0	0.0
9/13/83	0.0	0.0
9/14/83	2.6	4.2
9/15/83	0.0	0.0
9/16/83	0.0	0.0
9/17/83	7.2	14.9
9/18/83	0.0	0.0
9/19/83	0.0	0.0
9/20/83	0.0	0.0
9/21/83	0.0	0.0
9/22/83	0.0	0.0
9/23/83	0.0	0.0
9/24/83	0.0	0.0
9/25/83	7.5	15.5
9/26/83	8.1	17.7
9/27/83	13.6	29.1

Table C.2. Electrical usage of the compressor unit for the summer of 1984

Date	Hours of Operation	Kilowatt Hours
6/06/84	17.1	24.7
6/07/84	4.2	6.0
6/08/84	7.1	10.3
6/09/84	2.0	2.7
6/10/84	0.0	0.0
6/11/84	0.0	0.0
6/12/84	12.4	18.3
6/13/84	9.6	13.6
6/14/84	0.0	0.0
6/15/84	16.9	23.3
6/16/84	23.2	31.6
6/17/84	24.0	32.2
6/18/84	20.3	27.7
6/19/84	8.6	11.7
6/20/84	13.7	19.2
6/21/84	13.4	16.9
6/22/84	18.1	24.7
6/23/84	16.6	22.0
6/24/84	16.0	21.8
6/25/84	19.0	26.9
6/26/84	22.5	32.5
6/27/84	8.6	12.6
6/28/84	15.0	21.8
6/29/84	19.0	25.8
6/30/84	16.7	22.7
7/01/84	15.9	21.3
7/02/84	17.1	26.8
7/03/84	24.0	34.7
7/04/84	11.9	16.8
7/05/84	5.8	8.5
7/06/84	2.1	2.7
7/07/84	12.6	16.9
7/08/84	14.9	20.9
7/09/84	24.0	36.1
7/10/84	20.5	27.0
7/11/84	18.0	25.6
7/12/84	21.3	32.7
7/13/84	24.0	36.1
7/14/84	18.9	25.7
7/15/84	16.0	22.5
7/16/84	15.5	22.6
7/17/84	11.9	16.6

Table C.2. continued

Date	Hours of Operation	Kilowatt Hours
7/18/84	15.7	22.8
7/19/84	18.4	25.0
7/20/84	16.3	24.7
7/21/84	24.0	35.5
7/22/84	24.0	38.6
7/23/84	24.0	34.0
7/24/84	17.7	24.1
7/25/84	18.5	25.4
7/26/84	14.3	19.3
7/27/84	13.3	18.9
7/28/84	14.0	19.0
7/29/84	16.2	22.5

Table C.3. Summarized National Weather Service climatic temperature data for Sioux Falls, South Dakota for the months corresponding to electrical usage data

	Average Daily Highs	Average Daily Lows	Monthly Average (1)
August, 1983	90.9	65.7	78.3
September, 1983	76.8	50.1	63.5
June, 1984	78.8	57.3	68.1
July, 1984	85.0	62.1	73.6
August, 1984	86.0	62.4	74.2

(1): All temperature values are in degrees fahrenheit.

APPENDIX D: Sow and Litter Performance Data

Table D.1. Sow and litter data

Definition of Symbols
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T = treatment (0 for snout cooled, 1 for snout ventlilated, 2 for control)
Y = year (1 for 1982, 2 for 1983, 3 for 1984)

SN = sow number
SFW = sow farrowing weight (lbs.)
SWW = sow weaning weight (lbs.)
STF = sow total feed (lbs.)
LTFW = litter weight at farrowing (lbs.)
LWD7 = litter weight at day seven (lbs.)
LWW = litter weight at weaning (lbs.)

SFD = farrowing date (2)
SWD = weaning date (2)
SED = sow estrus date (2)
PF = number of piglets weighed at farrowwing
PGD7 = number of piglets weighed at day seven
PW = number of piglets weighed at weaning
DL = number of piglets which died during lactation

LN = how many litters sow has farrowed including present litter
AOT = average outside dry bulb temperature during lactation (degrees C)
AVOTHI = average outside temperature-humidity index during lactation, 0.75*Tdb+0.25*Twb (degrees C)
N1 = number of days of lactation with average daily outside temperature at or above 21 degrees C
N2 = number of days of lactation with average daily outside temperature at or above 24 degrees C
N3 = number of days of lactation with average daily outside temperature at or above 27 degrees C

T	Y	SN	SFD	SFW	SWD	SWW	SED	STF	PF	LT FW	PG D7	LW D7	PW	LWW	D L	LN	AOT	AVO THI	N1	N2	N3
0	1	47	932	447	950	409	955	262	16	55	12	72	12	146	.	.	23.9	22.6	15	9	3
0	1	24	926	457	950	418	955	312	11	34	11	50	11	133	.	.	23.5	22.2	19	12	3
0	1	45	932	423	950	423	955	250	10	30	9	49	9	114	.	.	23.9	22.6	15	9	3
0	1	79	957	349	985	346	989	429	13	43	10	50	9	121	.	.	22.4	21.4	20	11	3
0	1	07	964	475	985	493	989	287	10	27	7	47	7	96	.	.	21.6	20.7	14	7	0
0	1	43	957	487	985	466	989	438	11	28	11	50	10	157	.	.	22.4	21.4	20	11	3
0	1	77	932	504	958	479	963	378	9	26	11	50	11	138	.	.	23.9	22.8	23	14	4
0	1	19	937	407	958	383	962	355	12	40	11	66	10	141	.	.	23.7	22.8	19	11	2
0	1	63	935	340	958	327	964	366	15	46	11	68	11	138	.	.	23.5	22.5	20	11	2
0	1	87	965	475	991	450	996	419	14	44	10	49	9	127	.	.	20.9	20.0	14	6	0
0	1	81	965	345	991	337	996	356	12	31	10	49	10	133	.	.	20.9	20.0	14	6	0
0	1	05	965	453	991	413	995	391	8	29	10	68	9	162	.	.	20.9	20.0	14	6	0
0	1	53	994	415	22	350	27	384	12	53	12	88	12	216	.	.	15.4	14.8	2	2	0
0	1	86	994	310	22	287	27	373	11	41	11	56	11	152	.	.	15.4	14.8	2	2	0
0	1	83	994	346	22	276	27	309	11	40	11	66	11	180	.	.	15.4	14.8	2	2	0
0	1	30	6	478	28	467	32	420	8	29	7	44	7	114	.	.	13.0	12.4	0	0	0
0	1	28	12	517	28	480	33	368	11	43	11	67	11	123	.	.	13.5	12.9	0	0	0
0	1	77	998	486	28	470	33	480	9	29	11	67	11	171	.	.	14.2	13.6	1	1	0
0	1	18	932	464	950	459	954	280	11	36	9	55	9	118	.	.	23.9	22.6	15	9	3
0	1	38	932	557	950	537	955	256	11	42	10	59	10	120	.	.	23.9	22.6	15	9	3
0	1	17	932	530	950	536	955	196	10	19	10	33	6	58	.	.	23.9	22.6	15	9	3
0	1	46	957	409	985	361	989	404	11	33	10	58	10	176	.	.	22.4	21.4	20	11	3
0	1	62	957	424	985	388	989	446	9	27	10	63	10	158	.	.	22.4	21.4	20	11	3
0	1	53	937	458	958	549	962	340	11	35	10	52	9	113	.	.	23.7	22.8	19	11	2
0	1	51	935	338	958	327	962	305	8	26	11	67	11	147	.	.	23.5	22.5	20	11	2

(2): Dates are based on a thousand day calendar with Day 900 = June 1, 1982, Day 265 = June 1, 1983, Day 631 = June 1, 1984

Table D.1. continued

T	Y	SN	FD	SFW	WD	SWW	SED	STF	PF	LT FW	PG D7	LW D7	PW	LWW	D L	NL	AOT	AVO THI	N1	N2	N3
0	1	22	936	345	958	329	962	309	11	46	11	68	10	130	.	.	23.7	22.7	20	11	2
0	1	37	957	517	985	546	990	446	12	22	9	36	9	122	.	.	22.4	21.4	20	11	3
0	1	22	964	478	991	422	996	424	13	41	10	65	10	164	.	.	21.0	20.2	15	7	0
0	1	49	965	476	991	412	995	293	12	39	11	64	11	153	.	.	20.9	20.0	14	6	0
0	1	80	965	312	991	292	996	325	7	24	10	57	10	136	.	.	20.9	20.0	14	6	0
0	1	55	998	489	22	442	27	383	10	23	10	58	10	138	.	.	14.6	14.0	1	1	0
0	1	91	994	312	22	250	27	329	10	27	10	57	10	138	.	.	15.4	14.8	2	2	0
0	1	31	998	441	28	425	32	406	14	36	10	45	8	122	.	.	14.2	13.6	1	1	0
0	1	24	998	600	28	564	32	480	12	38	10	65	10	177	.	.	14.2	13.6	1	1	0
0	1	94	17	472	36	451	40	457	11	42	.	.	12	152	.	.	11.7	11.3	0	0	0
0	1	90	994	309	22	250	.	314	11	41	11	62	10	165	.	.	15.4	14.8	2	2	0
0	1	.	.	.	929	482	933	319	9	28	10	80	9	104	.	.	.	.	.	.	.
0	1	17	905	.	929	311	955	322	10	33	10	73	10	136	.	.	18.3	17.2	4	3	0
0	1	29	907	.	929	427	935	326	9	36	10	64	10	155	.	.	18.4	17.3	4	3	0
0	1	60	901	.	921	519	926	258	8	19	11	73	11	121	.	.	16.7	15.7	1	0	0
0	1	12	901	.	921	548	926	278	14	27	8	43	8	80	.	.	16.7	15.7	1	0	0
0	1	60	905	.	921	400	928	220	9	36	9	59	9	110	.	.	16.9	15.9	1	0	0
0	1	65	905	.	921	529	926	229	12	34	12	57	12	108	.	.	16.9	15.9	1	0	0
0	1	38	905	.	929	433	933	322	14	45	10	84	10	139	.	.	18.3	17.2	4	3	0
0	1	39	905	.	929	397	934	360	12	34	10	54	10	138	.	.	18.3	17.2	4	3	0
0	1	87	905	.	929	525	933	353	9	24	9	55	9	107	.	.	18.3	17.2	4	3	0
0	1	38	901	.	921	454	926	283	8	14	12	78	12	128	.	.	16.7	15.7	1	0	0
0	1	34	901	.	921	421	926	245	10	28	12	86	12	138	.	.	16.7	15.7	1	0	0
2	1	76	926	438	944	431	948	233	11	40	10	58	10	107	.	.	23.1	21.8	14	8	2
2	1	76	925	505	944	463	948	261	12	42	11	60	11	108	.	.	23.0	21.7	14	8	2
2	1	14	924	518	944	474	949	274	10	40	8	59	8	114	.	.	22.7	21.5	14	8	2
2	1	98	924	510	944	467	949	312	12	37	10	57	10	137	.	.	22.7	21.5	14	8	2
2	1	56	915	364	939	335	943	244	10	30	8	40	7	90	.	.	21.2	19.9	11	8	2
2	1	20	916	357	939	305	943	257	11	35	10	58	10	135	.	.	21.3	20.0	11	8	2
2	1	1	924	583	939	558	943	205	7	31	9	57	9	100	.	.	22.9	21.5	10	7	2
2	1	15	916	354	934	298	939	194	11	38	10	62	9	103	.	.	20.9	19.5	7	6	2
2	1	64	957	520	979	524	984	346	9	24	9	44	9	101	.	.	22.6	21.7	16	9	3
2	1	48	957	371	979	305	986	180	12	34	11	50	10	89	.	.	22.6	21.7	16	9	3
2	1	16	957	446	979	432	984	302	16	48	12	64	11	129	.	.	22.6	21.7	16	9	3
2	1	2	937	534	964	524	969	320	7	25	8	43	8	128	.	.	24.1	23.1	24	15	5
2	1	74	943	465	964	448	969	307	15	56	12	61	11	113	.	.	24.6	23.6	19	14	5
2	1	79	943	440	964	460	969	273	9	24	11	57	10	107	.	.	24.6	23.6	19	14	5
2	1	83	952	436	973	381	977	322	12	34	12	59	12	129	.	.	22.7	21.7	15	9	4
2	1	66	943	455	973	416	978	322	13	35	11	49	9	120	.	.	23.3	22.3	23	16	5
2	1	43	943	459	973	425	978	313	12	27	10	46	10	129	.	.	23.3	22.3	23	16	5
2	1	52	979	446	2	383	7	443	13	43	12	75	12	181	.	.	20.4	19.6	8	4	0
2	1	32	971	516	2	487	7	451	8	29	11	64	11	182	.	.	20.9	20.1	14	7	0
2	1	71	970	457	2	430	7	486	12	34	11	45	10	157	.	.	20.8	20.0	14	7	0
2	1	25	985	480	10	456	14	411	13	32	11	68	11	154	.	.	17.8	17.2	4	2	0
2	1	51	985	538	10	512	15	411	15	49	10	61	10	125	.	.	17.8	17.2	4	2	0
2	1	87	985	341	10	297	18	314	8	24	11	64	11	121	.	.	17.8	17.2	4	2	0
2	1	11	989	465	20	416	24	502	12	30	10	61	10	180	.	.	16.4	15.7	3	2	0
2	1	26	989	459	20	452	25	447	13	45	11	66	10	166	.	.	16.4	15.7	3	2	0
2	1	89	989	349	20	332	25	454	9	22	9	45	9	148	.	.	16.4	15.7	3	2	0

Table D.1. continued

T	Y	SN	SFD	SFW	SWD	SWW	SED	STF	PF	LT FW	PG D7	LW D7	PW	LWW	D L	NL	AOT	AVO THI	N1	N2	N3
2	1	60	12	461	36	473	41	392	9	26	8	41	8	118	.	.	12.1	11.6	0	0	0
2	1	80	926	501	944	488	949	252	10	37	10	56	10	105	.	.	23.1	21.8	14	8	2
2	1	53	925	372	944	322	952	220	8	29	11	73	11	134	.	.	23.0	21.7	14	8	2
2	1	56	924	469	939	456	943	252	14	55	10	57	10	98	.	.	22.9	21.5	10	7	2
2	1	59	924	404	939	380	946	264	12	49	11	77	11	130	.	.	22.9	21.5	10	7	2
2	1	40	910	420	934	360	939	274	11	28	12	61	11	144	.	.	20.2	18.9	8	6	2
2	1	57	910	367	934	345	939	279	7	23	10	50	10	120	.	.	20.2	18.9	8	6	2
2	1	61	910	489	934	470	938	344	12	39	11	58	11	124	.	.	20.2	18.9	8	6	2
2	1	42	913	457	934	442	938	289	9	30	9	52	9	108	.	.	20.4	19.1	7	6	2
2	1	57	910	603	934	558	939	344	10	35	10	56	9	133	.	.	20.2	18.9	8	6	2
2	1	18	952	457	979	422	985	338	9	28	12	57	12	146	.	.	22.8	21.9	21	12	4
2	1	51	952	455	979	435	984	389	13	35	11	48	11	143	.	.	22.8	21.9	21	12	4
2	1	50	952	468	979	430	984	364	10	30	12	56	12	151	.	.	22.8	21.9	21	12	4
2	1	17	943	464	964	467	969	244	12	40	8	41	8	86	.	.	24.6	23.6	19	14	5
2	1	64	941	388	964	318	969	222	8	30	9	56	9	128	.	.	24.4	23.4	21	14	5
2	1	3	938	479	964	471	968	345	12	33	11	47	9	120	.	.	24.1	23.1	23	14	5
2	1	55	943	563	973	521	977	365	11	26	10	53	10	157	.	.	23.3	22.3	23	16	5
2	1	66	943	390	973	370	977	380	8	26	10	62	10	162	.	.	23.3	22.3	23	16	5
2	1	86	943	364	973	328	977	326	10	29	11	56	11	154	.	.	23.3	22.3	23	16	5
2	1	84	970	363	2	313	7	349	8	28	10	55	10	180	.	.	20.8	20.0	14	7	0
2	1	85	972	317	2	276	7	344	10	26	9	45	9	136	.	.	21.0	20.2	14	7	0
2	1	70	982	400	2	326	7	263	11	40	10	65	10	124	.	.	20.0	19.2	5	2	0
2	1	71	989	429	10	404	16	356	11	39	10	71	10	133	.	.	17.6	17.1	3	2	0
2	1	4	985	557	10	539	14	423	11	31	9	49	9	120	.	.	17.8	17.2	4	2	0
2	1	89	985	484	10	482	15	377	14	36	10	60	10	127	.	.	17.8	17.2	4	2	0
2	1	27	989	574	20	565	24	500	13	26	8	31	8	131	.	.	16.4	15.7	3	2	0
2	1	9	989	527	20	479	24	527	9	26	9	59	9	166	.	.	16.4	15.7	3	2	0
2	1	28	12	467	28	478	32	242	3	9	7	25	6	46	.	.	13.5	12.9	0	0	0
2	1	66	12	493	36	456	40	383	10	28	9	56	9	142	.	.	12.1	11.6	0	0	0
2	1	13	12	412	36	383	41	396	13	27	9	51	9	121	.	.	12.1	11.6	0	0	0
2	1	54	17	478	36	460	41	387	12	42	.	.	9	119	.	.	11.7	11.3	0	0	0
2	1	88	989	358	20	283	.	376	8	24	10	68	9	157	.	.	16.4	15.7	3	2	0
2	1	25	924	378	939	344	.	165	10	38	10	69	10	111	.	.	22.9	21.5	10	7	2
2	1	92	17	528	36	533	40	280	9	28	.	.	7	94	.	.	11.7	11.3	0	0	0
0	2	345	354	419	378	365	383	310	10	32	10	51	10	142	0	.	17.9	17.1	9	7	3
0	2	370	347	313	378	283	382	351	11	35	10	48	10	173	1	.	19.7	18.9	16	13	6
0	2	369	347	366	378	328	382	431	10	43	10	58	9	184	1	.	19.7	18.9	16	13	6
0	2	333	331	430	350	390	355	279	11	43	11	62	11	130	0	.	25.3	24.2	18	15	5
0	2	336	328	424	350	383	355	309	12	43	12	61	12	127	0	.	25.5	24.5	21	18	6
0	2	226	321	476	342	.	346	166	11	37	11	62	11	110	0	.	25.3	24.3	20	16	7
0	2	302	321	486	350	418	354	401	13	40	12	68	11	190	2	.	25.4	24.4	28	23	8
0	2	239	321	486	342	450	346	322	11	35	11	57	11	130	0	.	25.3	24.3	20	16	7
0	2	299	321	479	342	440	348	289	11	41	10	60	10	134	1	.	25.3	24.3	20	16	7
0	2	228	292	503	319	437	324	288	13	43	12	66	12	160	1	.	24.8	23.8	22	18	10
0	2	283	285	437	312	375	316	348	10	49	10	89	10	188	0	.	24.0	23.1	20	16	7
2	2	360	300	396	325	337	.	267	11	41	11	67	11	156	0	.	26.0	24.9	24	20	11
2	2	292	305	486	330	446	334	328	11	35	11	67	11	144	0	.	25.8	24.8	24	19	10
2	2	288	305	475	325	389	332	199	11	43	11	90	11	156	0	.	25.8	24.8	19	15	8
2	2	295	308	512	330	483	335	296	10	41	10	69	10	138	0	.	25.8	24.9	22	17	9

Table D.1. continued

T	Y	SN	SFD	SFW	SWD	SWW	SED	STF	PF	LT WF	PG D7	LW D7	PW	LWW	D L	LN	AOT	AVO THI	N1	N2	N3
2	2	296	335	444	363	397	369	390	10	30	10	61	10	162	0	.	24.6	23.6	24	19	7
1	2	294	308	458	330	426	335	216	9	40	9	66	9	128	0	.	25.8	24.9	22	17	9
1	2	332	308	422	330	378	334	248	9	42	9	65	9	136	1	.	25.8	24.9	22	17	9
1	2	321	312	397	337	353	350	257	9	31	9	54	9	130	0	.	25.5	24.6	24	18	10
1	2	367	347	340	369	325	374	267	10	30	10	42	10	115	0	.	22.9	22.0	16	13	6
1	2	273	314	491	337	432	341	218	8	33	9	54	8	110	3	.	25.3	24.3	22	16	8
2	2	361	300	462	325	399	331	231	13	45	10	55	10	142	1	.	26.0	24.9	24	20	11
0	2	241	285	482	312	435	316	305	10	35	9	59	9	160	3	.	24.0	23.1	20	16	7
0	2	253	285	474	312	423	316	360	14	50	10	69	10	184	0	.	24.0	23.1	20	16	7
0	2	274	354	495	384	436	388	404	10	36	10	58	10	160	0	.	17.6	16.7	10	8	3
0	2	341	346	451	378	361	383	317	7	28	11	60	10	165	1	.	19.8	19.0	17	14	6
2	2	331	309	411	330	415	335	321	10	40	9	56	9	108	1	.	25.7	24.8	21	16	8
2	2	167	309	508	330	484	335	300	10	36	9	51	9	107	2	.	25.7	24.8	21	16	8
0	2	80	354	551	384	496	.	412	9	33	10	55	10	140	0	.	17.6	16.7	10	8	3
1	2	20	340	463	369	438	374	391	15	45	12	69	12	162	0	.	23.8	22.8	23	20	8
2	2	338	335	418	363	369	371	277	13	38	9	48	9	132	2	.	24.6	23.6	24	19	7
2	2	242	335	565	363	502	367	333	10	27	10	52	10	164	3	.	24.6	23.6	24	19	7
2	2	366	335	364	363	328	368	317	11	31	9	46	9	130	3	.	24.6	23.6	24	19	7
2	2	365	334	315	352	336	382	158	7	29	10	70	10	115	0	.	25.4	24.4	17	14	5
2	2	260	332	514	355	460	361	321	12	48	.	.	10	142	0	.	25.6	24.6	22	19	7
0	2	363	326	332	350	280	357	212	13	55	9	57	9	132	1	.	25.6	24.6	23	20	7
0	2	19	314	522	342	468	349	398	14	42	10	62	10	163	1	.	25.3	24.3	27	20	9
1	2	84	314	591	337	520	.	288	7	37	10	67	10	130	0	.	25.3	24.3	22	16	8
1	3	8	695	.	715	.	720	312	11	39	11	59	11	125	0	3	23.3	22.2	16	8	3
1	3	359	695	.	715	.	719	276	11	38	10	62	10	130	1	4	23.3	22.2	16	8	3
1	3	356	695	.	715	.	722	312	11	50	11	72	11	140	0	4	23.3	22.2	16	8	3
1	3	357	695	.	715	.	723	296	10	45	9	58	9	134	3	4	23.3	22.2	16	8	3
1	3	29	695	.	715	.	721	344	9	28	8	42	8	103	3	2	23.3	22.2	16	8	3
2	3	362	712	.	733	.	737	320	12	40	9	52	9	125	3	3	18.9	17.8	5	4	2
0	3	24	707	383	724	378	728	212	9	26	11	52	11	96	0	2	21.7	20.6	10	4	2
0	3	93	704	401	724	377	729	258	7	34	10	69	10	112	0	1	22.3	21.1	13	7	3
0	3	91	707	361	724	348	731	232	8	26	10	48	10	90	0	1	21.7	20.6	10	4	2
2	3	311	687	.	711	.	715	346	9	29	8	46	8	97	2	5	24.2	23.1	22	13	3
2	3	222	687	.	711	.	716	368	9	29	9	54	9	123	0	9	24.2	23.1	22	13	3
0	3	20	701	417	719	378	737	239	10	36	9	57	9	113	1	2	23.0	21.9	14	8	2
2	3	95	712	.	733	.	739	230	11	43	11	63	11	138	0	1	18.9	17.8	5	4	2
0	3	62	638	321	664	298	669	325	9	30	9	53	9	154	2	1	20.8	19.9	15	2	0
0	3	12	637	392	664	393	.	428	13	30	8	38	8	113	5	5	20.6	19.9	15	2	0
0	3	94	707	356	724	345	729	230	11	26	11	45	10	64	1	1	21.7	20.6	10	4	2
0	3	320	707	498	724	476	729	232	11	36	9	56	9	103	2	5	21.7	20.6	10	4	2
2	3	78	680	.	711	.	716	395	10	26	7	33	7	123	3	1	24.2	23.1	28	16	5
2	3	97	715	.	733	.	.	236	10	35	8	47	7	90	3	1	19.0	18.0	5	4	2
2	3	808	712	.	733	.	738	292	11	44	11	71	11	153	0	6	18.9	17.8	5	4	2
2	3	7	715	.	733	.	739	280	10	38	10	56	10	93	0	3	19.0	18.0	5	4	2
2	3	100	716	.	733	.	743	247	11	34	10	46	10	75	1	1	18.9	17.9	5	4	2
2	3	805	712	.	733	.	737	318	11	43	11	77	11	143	0	6	18.9	17.8	5	4	2
2	3	98	715	353	740	356	745	331	11	30	11	48	11	114	0	1	18.2	17.2	6	4	2
2	3	.	720	515	740	506	744	230	11	35	11	55	11	108	0	9	16.6	15.6	2	0	0
2	3	79	719	385	740	331	745	271	11	34	11	77	11	149	0	1	17.1	16.1	3	1	1

Table D.1. continued

T	Y	SN	SFD	SFW	SWD	SWW	SED	STF	PF	LT FW	PG D7	LW D7	PW	LWW	D L	LN	AOT	AVO THI	N1	N2	N3	
2	3	9	715	417	740	372	745	380	11	38	11	62	11	166	0	3	18.2	17.2	6	4	2	
2	3	318	715	.	733	.	.	296	11	39	11	70	11	134	4	5	19.0	18.0	5	4	2	
0	3	308	701	537	719	554	723	242	10	30	10	48	10	93	1	5	23.0	21.9	14	8	2	
0	3	92	701	342	719	353	725	251	10	26	10	48	10	96	0	1	23.0	21.9	14	8	2	
0	3	358	701	517	719	496	723	256	9	33	8	50	8	105	4	4	23.0	21.9	14	8	2	
0	3	107	701	404	719	392	723	252	10	33	10	54	9	101	1	3	23.0	21.9	14	8	2	
2	3	44	692	.	711	.	716	272	12	29	10	83	10	106	2	4	24.4	23.4	18	11	3	
2	3	6	687	.	711	.	716	368	10	37	10	58	9	120	1	3	24.2	23.1	22	13	3	
2	3	350	658	499	680	463	684	336	10	28	9	60	8	129	4	4	22.6	21.5	16	6	3	
2	3	264	654	482	680	450	.	420	6	24	10	82	10	168	1	7	22.5	21.4	19	6	3	
2	3	374	657	415	680	406	.	316	9	24	9	45	9	104	0	3	22.6	21.4	17	6	3	
2	3	67	657	345	680	339	685	280	8	25	8	44	7	103	2	1	22.6	21.4	17	6	3	
2	3	287	657	466	680	449	684	354	10	36	9	57	9	124	2	5	22.6	21.4	17	6	3	
2	3	138	657	525	680	534	.	344	9	28	9	50	9	110	0	13	22.6	21.4	17	6	3	
1	3	354	661	397	687	393	691	375	11	32	10	71	10	130	3	3	23.2	22.0	19	9	5	
1	3	3	669	483	687	450	691	240	10	30	.	.	10	109	0	3	23.7	22.5	13	6	5	
1	3	69	661	309	687	297	692	345	10	30	10	71	10	140	0	1	23.2	22.0	19	9	5	
1	3	68	661	331	687	291	696	348	10	30	10	76	10	143	0	1	23.2	22.0	19	9	5	
0	3	246	669	464	695	416	699	366	11	39	11	64	10	162	1	8	23.8	22.6	20	11	5	
0	3	34	669	380	695	368	699	388	10	32	10	53	10	149	0	2	23.8	22.6	20	11	5	
0	3	105	669	415	695	392	700	378	10	36	10	62	10	165	0	2	23.8	22.6	20	11	5	
0	3	76	669	392	695	350	699	350	11	31	11	57	11	153	1	1	23.8	22.6	20	11	5	
0	3	35	669	394	695	407	699	412	10	26	9	34	9	115	1	2	23.8	22.6	20	11	5	
0	3	12	680	487	700	462	705	256	10	40	10	66	10	132	0	2	24.5	23.4	18	11	4	
0	3	33	680	352	700	329	.	255	10	27	9	48	9	110	1	2	24.5	23.4	18	11	4	
0	3	351	675	528	700	517	705	380	12	42	12	71	11	172	1	4	24.0	22.9	21	11	4	
0	3	313	675	489	700	513	705	354	11	42	10	56	9	125	2	5	24.0	22.9	21	11	4	
0	3	353	675	456	700	405	705	384	12	30	12	58	12	160	0	4	24.0	22.9	21	11	4	
2	3	205	680	505	706	499	710	372	10	30	7	37	7	101	4	10	24.5	23.4	23	15	5	
2	3	1	680	360	706	348	710	380	10	32	10	53	10	123	0	3	24.5	23.4	23	15	5	
2	3	316	680	513	706	492	710	372	9	24	9	45	9	126	1	5	24.5	23.4	23	15	5	
2	3	317	680	523	706	488	710	372	10	40	10	58	10	146	0	5	24.5	23.4	23	15	5	
2	3	77	680	390	706	355	710	307	9	30	9	50	9	123	0	1	24.5	23.4	23	15	5	
2	3	65	651	337	678	304	682	254	10	34	10	64	10	142	0	1	22.2	21.1	18	6	3	
2	3	66	651	342	676	330	681	283	11	34	9	51	9	124	2	1	22.4	21.2	18	6	3	
2	3	64	651	334	676	282	681	290	10	45	10	69	10	142	0	1	22.4	21.2	18	6	3	
2	3	307	651	412	676	412	680	342	10	33	10	56	10	119	0	5	22.4	21.2	18	6	3	
0	3	63	644	410	670	362	675	372	11	25	11	52	10	138	1	1	21.8	20.8	19	4	1	
0	3	345	644	503	670	456	674	402	10	27	10	54	10	137	3	4	21.8	20.8	19	4	1	
0	3	113	644	429	670	367	675	408	11	30	11	63	11	162	0	2	21.8	20.8	19	4	1	
0	3	341	643	439	670	411	675	434	10	36	9	57	9	145	2	4	21.7	20.7	19	4	1	
0	3	365	644	481	670	430	676	420	11	43	11	77	11	176	0	3	21.8	20.8	19	4	1	
0	3	20	635	429	664	396	668	441	12	38	11	62	10	193	2	6	20.7	19.9	15	2	0	
0	3	.	635	455	664	440	668	441	11	35	9	51	9	176	2	8	20.7	19.9	15	2	0	
0	3	372	643	468	664	434	667	301	10	42	10	71	10	137	1	3	21.6	20.7	15	2	0	
0	3	369	644	453	664	409	669	315	11	50	11	96	11	169	1	3	21.7	20.8	15	2	0	
0	3	340	651	.	670	.	.	254	10	35	10	61	10	102	0	4	21.9	20.8	14	4	1	
0	2	192	295	558	319	530	.	295	6	23	11	52	10	138	1	.	.	.	.	.	.	(*)
0	2	231	292	475	319	441	323	268	12	32	12	56	11	134	2	.	.	.	.	.	.	(*)

Table D.1. continued

T	Y	SN	SFD	SFW	SWD	SWW	SED	STF	PF	LT FW	PG D7	LW D7	PW	LWW	D L	LN	AOT	AVO THI	N1	N2	N3
0	2	230	292	519	319	453	324	314	12	37	12	62	11	164	0	.	.	.	.	.	. (*)
0	2	225	292	560	319	518	324	362	12	33	12	53	9	144	0	.	.	.	.	.	. (*)
0	2	103	292	535	319	507	.	358	13	38	12	48	9	108	3	.	.	.	.	.	. (1)
0	2	325	292	387	312	353	317	171	10	31	11	61	10	112	1	.	.	.	.	.	. (*)
0	2	286	285	391	312	353	317	311	10	40	11	66	11	166	3	.	.	.	.	.	. (*)
0	2	255	285	541	312	518	316	403	13	35	11	58	10	166	3	.	.	.	.	.	. (*)
2	2	326	300	445	325	384	332	324	9	33	11	66	11	138	0	.	.	.	.	.	. (*)
2	2	160	300	460	325	458	.	288	9	30	11	50	9	126	1	.	.	.	.	.	. (1)
2	2	233	305	504	325	491	331	235	8	32	11	78	11	138	0	.	.	.	.	.	. (*)
2	2	323	308	456	330	.	.	189	7	29	9	59	9	124	0	.	.	.	.	.	. (1)
1	2	175	314	541	337	514	342	260	11	37	10	52	8	96	1	.	.	.	.	.	. (*)
0	2	300	321	510	342	469	346	306	8	30	11	74	11	142	1	.	.	.	.	.	. (*)
0	2	65	321	553	342	517	346	250	8	28	10	58	10	106	0	.	.	.	.	.	. (*)
0	2	362	326	366	350	339	354	296	7	38	11	61	10	124	0	.	.	.	.	.	. (*)
0	2	238	325	.	350	.	355	314	14	55	8	52	9	129	4	.	.	.	.	.	. (*)
2	2	364	328	330	355	290	360	176	11	40	9	40	7	110	2	.	.	.	.	.	. (1)
2	2	301	328	514	355	487	370	375	12	45	12	58	11	148	0	.	.	.	.	.	. (*)
2	2	334	330	.	355	400	360	265	9	36	11	66	10	152	1	.	.	.	.	.	. (*)
2	2	339	335	453	355	416	360	213	6	25	10	65	10	114	0	.	.	.	.	.	. (*)
1	2	156	340	525	369	494	374	402	15	49	12	62	11	142	2	.	.	.	.	.	. (*)
1	2	.	340	497	369	476	374	408	7	26	8	57	9	154	2	.	.	.	.	.	. (*)
2	2	340	341	426	363	390	392	270	9	36	11	57	10	94	1	.	.	.	.	.	. (*)
1	2	335	344	390	369	370	374	338	12	42	10	60	10	126	3	.	.	.	.	.	. (*)
0	2	214	354	530	384	488	388	353	11	34	8	47	8	110	2	.	.	.	.	.	. (*)
0	2	372	357	357	384	328	388	348	11	25	11	51	10	114	0	.	.	.	.	.	. (*)
0	2	219	357	495	384	416	388	356	6	19	10	62	10	140	1	.	.	.	.	.	. (*)

(*): indicates samples which were deleted due to piglet transfers

(1): indicates samples which were deleted due to various health problems